JOURNAL OF THE A·I·E·E·

FEBRUARY 1930

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

MEETINGS

of the

American Institute of Electrical Engineers

NORTH EASTERN DISTRICT MEETING No. 1, Springfield, Mass., May 7-10, 1930

SUMMER CONVENTION, Toronto, Ontario, Canada, June 23-27, 1930

PACIFIC COAST CONVENTION, Portland, Oregon, September 2-5, 1930

MIDDLE EASTERN DISTRICT MEETING, No. 2, Philadelphia, Pa., October 13-15, 1930

SOUTHERN DISTRICT MEETING, No. 4, Louisville, Kentucky, November 19-22, 1930

MEETINGS OF OTHER SOCIETIES

American Institute of Mining and Metallurgical Engineers Annual Meeting, New York, N. Y., February 17-21 (Doctor H. Foster Bain, Secretary, 29 West 39th St.)

The American Physical Society, Columbia University, February 21-22, (W. L. Severinghaus, Columbia University)

National Electric Light Association
North Central Division, Engineering Section, Nicollet Hotel, Minneapolis, Feb. 24-25. (J. W. Lapham, 803 Plymouth Building, Minneapolis, Minn.)

The American Society of Mechanical Engineers 50th Anniversary Meeting, April 5-9, New York, N. Y., and Washington, D. C. (C. W. Rice, Secretary, 29 West 39th St.)

JOURNAL of the A. I. E. E.

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

PUBLICATION COMMITTEE
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Changes of advertising copy should reach Institute headquarters by the 15th day of the month for the issue of the following month.

Subscription: $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines, $10.50 to Canada, Central America, South America, Haiti, Spain and Colonies, and $11.00 to all other countries.
Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

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Institute and Related Activities

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

—Some Activities and Services Open to Members—

Attendance at Conventions.—Taking part in the Institute conventions is one of the most useful and helpful activities which membership in the Institute affords. The advantages offered lie in two distinct channels; technical information and personal contacts. The papers presented are largely upon current problems and new developments, and the educational advantages of hearing and taking part in the discussion of these subjects in an open forum cannot but broaden the vision and augment the general knowledge of those who participate. Equally advantageous is the opportunity which conventions afford to extend professional acquaintances and to gain the inspiration which grows out of intimate contact with the leaders in electrical engineering. These conventions draw an attendance of from 1000 to 2000 people and constitute milestones in the development of the electrical art.

Presentation of Papers. An important activity of the Institute is the preparation and presentation of papers before meetings of the Institute. Opportunity is offered for any member to present a paper of general interest to engineers at an Institute meeting, or of having shorter contributions published in the JOURNAL without verbal presentation. In preparing a paper for presentation at a meeting the first step should be to notify the Meetings and Papers Committee about it so that it may be tentatively scheduled. Programs for the meetings are formulated several months in advance and unless it is known well in advance that a paper is forthcoming, it may be subject to many months delay before it can be assigned to a definite meeting program. Immediately upon notification the author will receive a pamphlet entitled "Suggestions to Authors" which gives in brief form instructions in regard to Institute requirements in the preparation of manuscripts and illustrations. This pamphlet contains many helpful suggestions and its use may avoid much loss of time in making changes to meet Institute requirements.

Manuscripts should be in triplicate and should be sent to Institute headquarters at least three months in advance of the date of the meeting for which they are intended; they are then submitted first to the members of the technical committee covering the subject of the paper, and if approved, will next go to the Meetings and Papers Committee for final disposal. After final acceptance the paper goes to the Editorial department for printing, which requires usually from two to three weeks. Advance copies are desired about ten days prior to the meeting in order to distribute the paper to members desiring to discuss it. Considering the routine through which all papers must pass, the advantage of prompt notification and early submission of manuscripts will be apparent.

Publications of the A. I. E. E.—The chief publications of the Institute are the JOURNAL, QUARTERLY TRANSACTIONS, A. I. E. E. STANDARDS, and the YEAR-BOOK.

The JOURNAL, a monthly publication which every member receives, contains two sections, one devoted to technical papers, and the other to current activities of the Institute and other related subjects of engineering interest. The technical section consists largely of rather complete abridgments of the papers presented at conventions and meetings of the Institute. These are brief enough to enable the reader to keep posted in the various fields of engineering which the papers cover; and complete copies of any paper are sent gratis to the reader who wishes to specialize on any subject. The second section of the JOURNAL is designed to keep members acquainted with the activities of the Institute and with the news of the engineering world in general.

The QUARTERLY TRANSACTIONS contain the papers and discussions at Institute meetings and are the only publications in which they are printed in full. These volumes are designed principally for reference books, and are furnished to members at a very nominal cost. These volumes practically constitute the history of the art of electrical engineering, as they contain papers covering every major electrical development.

The A. I. E. E. STANDARDS which were formerly published in a single book have so increased in volume that they are now divided into more than thirty individual sections and the number is constantly growing. This arrangement gives greater latitude in publishing revisions of any sections promptly, and convenient binders are furnished for filing all the individual sections under one cover. An index for the complete set is also available. The standards are supplied to members at a very small cost.

The YEAR-BOOK is published annually and contains an alphabetical and a geographical list of members corrected to January first each year. It also includes a section giving general information about the Institute, the Constitution, By-laws, Code of Principles of Professional Conduct and the Annual Report of the Board of Directors. The Year-Book is sent free to members on request.

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

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A Message From the President.

The Publications of the Institute

THE principal publications of the Institute may be divided into three distinct types to serve three distinct purposes.

The most important annual publication is the Year Book, which is mainly statistical and provides a permanent record of purpose, activity, membership and organization of the Institute. The Constitution and By-Laws and similar information are included.

The TRANSACTIONS of the Institute, formerly an annual publication, has been, for some years, a quarterly issue printing in full all papers and their discussion which have been accepted by the Institute for presentation and publication. Many members of the Institute do not yet appreciate the fact that the quarterly TRANSACTIONS contain *all* papers in *full* that have been so accepted. This continuous and complete record of the most important activity of the Institute in the "advancement of the theory and practise of electrical engineering" has been, from the beginning, the outstanding and most important accomplishment of the Institute. It is hoped and believed that it will always remain the policy of the Institute that the name, TRANSACTIONS, shall continue to be fully applicable.

The JOURNAL of the Institute, by its name, implies that it is the current and frequent periodical designed to keep the membership informed, monthly or otherwise, as to the activities in this most vigorous branch of science and engineering. To this inclusive professional organization the technical world looks for authoritative information of advances in electrical engineering and allied arts and sciences. A most thorough and careful consideration should be given at the present time to what constitutes an advisable editorial policy for the JOURNAL for the future. The Publication Committee requested advice from the membership on this question a year ago,* and is studying the whole matter. Both the Meetings and Papers Committee and the Publication Committee are making active effort to accomplish a solution of this,—one of the most important problems before the Institute. The interests of the thousands of Institute members are becoming more and more diversified and divergent as new subdivisions of electrical science and art develop each year. The problem has many angles. The questions of editorial policy and most effective content of the JOURNAL as a monthly publication for Institute membership arise and become insistent because of these facts and need solution.

Can an acceptable and desirable editorial policy for the JOURNAL be set up which would give the membership of the Institute, through the JOURNAL, uniformly classified and consistently brief abstracts of all papers as soon as, or in advance of, presentation? These abstracts to be, without waste of space or time, sufficient to inform every reader so that he may determine if he should send for advance copy of the full paper, as at present conveniently provided, or await the receipt of the quarterly volume of the TRANSACTIONS. The balance of the released space in the JOURNAL may be employed for printing the best of the papers presented at Section or Branch meetings; many of these, even if not of permanent value, are noteworthy and of lively interest, but never reach the general membership. Other papers of broad and timely interest might be included in the JOURNAL content even though they lack permanent value, which would warrant inclusion in the TRANSACTIONS.

Does the membership favor such a policy? If so, it is believed it can be accomplished.

Harold B. Smith

President.

*JOURNAL, A.I.E.E., January 1929.

Some Leaders of the A. I. E. E.

Charles Edward Skinner, Assistant Director of Engineering, Westinghouse Electric & Manufacturing Co., a Manager of the Institute 1915-19 and one of its Vice-Presidents 1919-20, was born on a farm near Redfield, Ohio, May 30, 1865. He was educated at Ohio University and Ohio State University, being graduated from the latter with a M. E. degree with the class of 1890. He worked his way through the University, partly as a helper at the Ohio Experimental Station Dairy and partly as a machinist in the University shops. In August, after graduating in June, he joined the organization of the Westinghouse Electric and Manufacturing Company as a machinist in charge of the manufacture of railway controllers and supervised the construction of the first controllers turned out by the Westinghouse Company. Early in 1891 he was asked to undertake the development of a system for the testing of insulation: this required the development of testing apparatus, testing methods, and later he was put in charge of all insulation design, as well as testing.

In addition to the insulation work, he took up magnetic testing and the development of magnetic materials in 1892, and retained charge of this work for many years.

In connection with his work, Mr. Skinner organized the material specifications work and personally wrote most of the Company's early Purchasing Department Specifications. In 1902 he organized the Insulation Division of the Engineering Department and continued in charge of the material testing and Purchasing Department specifications. At about the same time, he organized the process engineering work, which has to do with putting in specification form shop processes of every character.

In 1906 Mr. Skinner organized the research division of the Engineering Department, and was responsible for the organization and equipment of the Chemical, Physical and Process Laboratories, as well as the High-Tension Test Laboratory.

Through his efforts a laboratory for more fundamental research was determined upon in 1915, and in 1920 he was made Manager of the Research Department, taking direct and individual charge of the Research Laboratory for the next two years. In 1922 he was made Assistant Director of Engineering.

Mr. Skinner went to Brussels in 1906 as American representative of the International Association for Testing Materials. In 1915 he was a special delegate from the A. I. E. E. to confer with the British Engineering Standards Committee. In 1920 he was Chairman of the American Delegation to the Brussels Meeting of the International Electrotechnical Commission, and held a similar position at the meeting of the International Electrotechnical Commission in Geneva, Switzerland, in the Fall of 1922. He was a member of the American Delegation to the International Electrotechnical Commission meeting in London in 1924, The Hague in 1925, New York in 1926 and Bellagio in 1927. He was a delegate to the World Power Conference in London in 1924.

Mr. Skinner was Chairman of the American Engineering Standards Committee the years of 1925, 1926, and was elected Chairman of the Committee of the organization of the International Standards Association.

Mr. Skinner was a member of the Engineering Council throughout its life, and is a member of the American Engineering Council, the successor of the Engineering Council. He is a Fellow of the American Institute of Electrical Engineers and has served as Manager and Vice President. He was Chairman of a Special Committee appointed by the Electrical Manufacturers Council, at the request of Mr. Herbert Hoover, then Secretary of Commerce, to work with the Department of Commerce and Bureau of Standards. He has been a member of the Standards Committee of the American Institute of Electrical Engineers for many years. As past chairman of the American Engineering Standards Committee he becomes a member of the Board of Directors of the American Standards Association.

Mr. Skinner is a member of the Franklin Institute, American Society for Testing Materials, Fellow of the American Association for the Advancement of Science, member of the American Society of Mechanical Engineers, member of the Engineers' Society of Western Pennsylvania, Fellow of the American Institute of Electrical Engineers, member of the National Electrical Manufacturers Association, the American Physical Society, the American Electrochemical Society, the American Petroleum Institute, the Philosophical Society of Pittsburgh, the Engineers' Club of New York, the United States Committee of the International Electrotechnical Commission, and the University Club of Pittsburgh. He was appointed a delegate to the International Engineering Congress held in Japan in October, 1929, acting as Chairman of the American Electrochemical Society's delegation and a member of the American Standards Association's delegation to the Congress. In 1927 he received the Honorary Degree of Doctor of Science from the Ohio University.

Mr. Skinner has represented the Westinghouse Electric and Manufacturing Company in construction and testing work in many parts of the United States, Canada, and Mexico. His published writings consist of papers on Insulation, Testing, Magnetics, Research, Standardization, etc.

In addition to those already mentioned Mr. Skinner has served on the following Committees of the Institute: Edison Medal, Executive, Public Policy, Principles of Professional Conduct, Meetings and Papers, Research, Electrical Machinery, Educational and Electrophysics.

Controlling Power Flow with Phase-Shifting Equipment*

BY W. J. LYMAN†

Associate, A. I. E. E.

Synopsis.—*In the operation of an electric power distributing system involving various kinds of networks, a fundamental necessity is that each transforming and transmitting unit carry a reasonable share of the total load. In the case of a single system that has been developed in a coordinated manner the problem of load division has not in general been troublesome and has been solved by judicious selection of parallel circuits, use of reactors, proper system set-up, etc. The advent of inter-company connections has brought together systems of varying characteristics, changed the relation between the basic elements involved, and in some cases has made difficult the control of power flow over tie lines small in comparison to the systems which they unite.*

It is the purpose of this paper to discuss the case of load control where closed rings or parallel path circuits are involved. After briefly reviewing the principles of voltage phase angle and power flow, a description is given of some actual tests performed on a very large interconnected system with a 250-mi. transmission loop, involving five power companies and a total generator capacity well over 1,000,000 kw. The results of these measurements are analyzed for the purpose of checking theoretical against actual values and forming a basis for the solution of problems of a similar nature.

* * * * *

Introduction

It is a generally recognized fact that one of the most important and sometimes the most perplexing problems encountered in the operation of inter-company connections is that of securing accurate and flexible means of regulating power flow. This is a problem which rapidly becomes more complex with the increase in the number of systems combined through interconnection into one group. Inter-company contracts, tie line capacity, and internal system limitations often require that the load exchanged at the various points be regulated within rather definite limits. Conditions have arisen where the maintenance of proper load division has been very difficult if not impossible and attention has already been directed to the solution of this important problem. Although efforts are being made to broaden interchange contract requirements it is sometimes difficult to avoid exceeding physical limitations and to secure the most efficient over-all operation.

It is the purpose of this paper to discuss experimental and analytical methods by which the fundamental problem of load control may be attacked.

At this point it may be well to mention that the problems of inter-company connection differ only in magnitude from conditions existing within most systems and cases undoubtedly exist where the same treatment might be applied to secure more flexible and economical inter-company operation.

The Problem

When two companies are tied together at one point and have no other interconnection, the problem of load control is relatively simple. Should Company I generate say 10,000 kw. in excess of its own load, there can be but one result; the 10,000 kw. must go over the tie line to Company II. Obviously, if this exchange is to be secured without frequency variation, the increase in generator output by Company I must be carefully coordinated with a corresponding decrease in output of prime movers by Company II. The maintenance of adequate system stability, power factor control, etc., are then the chief problems. If Company II is connected in turn to a third Company III, the three not forming a closed loop, the problem of load control is very similar but somewhat more involved. Proper apportionment can be secured through governor speed adjustments for any number of series connections, the regulation becoming more difficult as the number of companies increases.

If, however, the interconnected systems form a closed loop, an entirely new element enters the problem and results in conditions which cannot be corrected by governor adjustment. In other words, if the three companies in the preceding example are connected to form a triangle, an adjustment of load on the tie between I and II would result in power flow in the other two lines. An investigation soon reveals the fact that the three exchanges cannot be independently controlled and that an analysis and solution is best facilitated by the conception of voltage-phase relations.

Phase Angles

Considering once more the case of two interconnected companies, the conditions which exist are practically identical with those which accompany the transmission of power over any typical circuit. This is illustrated by the single-phase vector diagram of Fig. 1. It is apparent that the transmission of power from I to II results not only in a difference in magnitude between terminal voltages (in this case V_{II} is less than V_I), but also a shift in phase angle denoted by the angle θ. In actual practise the phase shift is not always apparent, but the drop in voltage magnitude is often objectionable

*Part V of a Symposium on Power System Planning.

†Electrical Planning Engineer, Duquesne Light Company, Pittsburgh, Pa.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Printed complete herein.

and can be readily corrected by transformer taps, voltage regulators, or power factor control.

The addition of a third system to form a loop is illustrated in Fig. 2. With the same interchange of 10,000 kw. from I to II and with the tie line 2-3 open, voltage relations will be the same as in Fig. 1. With no

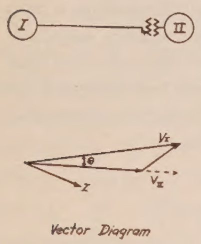

Fig. 1

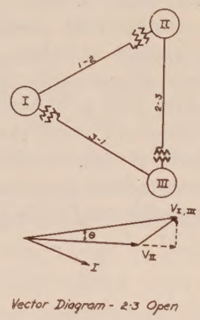

Fig. 2

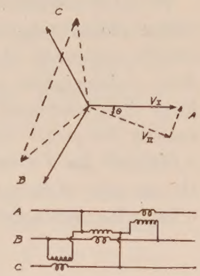

Fig. 3

Figs. 1, 2, 3—Voltage-Phase Displacement and Correction

Fig. 1—Two systems
Fig. 2—Three systems
Fig. 3—Phase rotator

transfer between I and III, their voltages will be practically equal and in phase. By means of regulator adjustments, it would be possible to secure voltages at the open circuit, equal in magnitude but not in the same phase position. Reference to Fig. 2 illustrates this condition and shows that there would be across the open switch a voltage about 90 deg. out of phase with the line voltage. A convenient method of attack is to consider that closing the switch will superimpose on the existing loadings around the loop a circulating power determined by the magnitude of the quadrature voltage and the total effective impedance, the direction of flow being from leading to lagging voltage.

Conditions similar to that just outlined often arise in the operation of actual systems. Sometimes the differences in phase angle at a tie point are such as to make satisfactory operation impossible. These variations are produced as a result of conditions of unsymmetrical system set-up and loading such as: difference in per cent reactance of cable and open wire lines, unequal number of transformations, location of power plants near the end of the transmission system, and non-uniform loading.

In order to prevent this circulating power which might upset exchange values, voltage conditions, and loading around the circuit, it would be necessary to introduce a quadrature voltage any place in the loop equal to the inherent displacement produced by circuit loading. A simple method of producing this correction would be to connect transformers as in Fig. 3. By connecting the secondary of a regulating transformer in one phase and the primary across the other two phases, a voltage at 90 deg. may be obtained. It can be shown that for ordinary transmission circuits, the power flow is nearly proportional to the phase displacement of the voltage. It is feasible, therefore, to obtain accurate and flexible control of power exchange by supplying some equipment which will produce the required quadrature voltage in adjustable amounts and direction.

Adding a voltage at right angles to the line voltage begins to change the magnitude as well as the direction for the larger angles. Because of this fact it may be economical to combine voltage control with phase shifting in one equipment. This can readily be achieved by one tap changing transformer and two sets of series transformers using star and delta connections. The basic principle is illustrated in Fig. 4.

By laying out the transmission ring with all impedances and given simultaneous loads it is possible to calculate the required amount of phase shift for any assumed set of conditions. In this connection it should be emphasized that the so-called "velocity of electricity" has no effect on the phase displacement even for very long lines. The "velocity" of 186,000 miles per second applies only to transients and not to steady-state conditions.

Obviously, the success of any such installation depends on the accuracy and foresight represented in the phase-angle determination. It was for the purpose

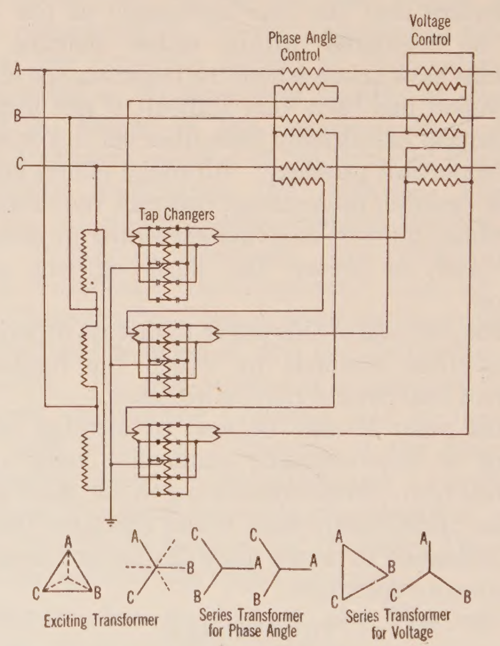

Fig. 4—Diagram of Equipment for Shifting Phase-Angle and Regulating Voltage

of establishing a workable method of making such calculations and checking theoretical and actual values that a test was performed and analyzed on a high-tension transmission ring about 250 mi. around and involving five systems.

The following discussion, it should be remembered, pertains only to cases where a closed loop or parallel path network exists.

Description of Tests

The high-tension transmission ring which was investigated on this test is shown simplified on the diagram of Fig. 5. The systems of the West Penn Power Company, Ohio Power Company, Ohio Public Service, Pennsylvania and Ohio Power and Light Company, and the Duquesne Light Company were

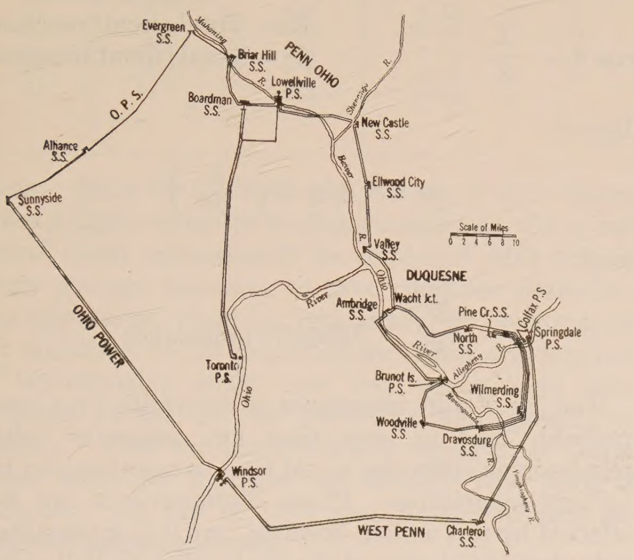

Fig. 5—Map Showing Transmission Lines Devolved in Interconnection Test of April 16, 1928

involved. Occasional operation with this ring closed on itself had demonstrated the inflexibility of interchange control.

The method of procedure followed to obtain the desired readings was:

1. With the tie line open at Valley Substation of Duquesne Light Company, all other connections being closed, measure the phase displacement at this point

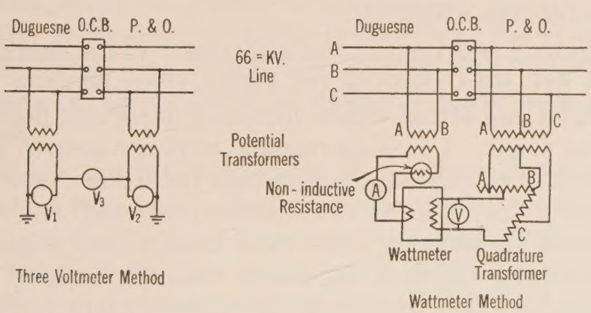

Fig. 6—Phase-Angle Measurement

and at the same time secure readings of magnitude and direction of power flow on all parts of the ring, together with existing voltage conditions.

2. Close the tie breaker at Valley Substation and determine the amount of power flow corresponding to the measured angle. A record was also made of power station and circuit loading all around the ring.

3. Open the tie breaker at Valley and repeat the readings of No. 1.

4. Secure all these readings for various values of initial phase angle. The variations are obtained by shifting generation between power stations with resulting changes in tie line loads as illustrated on Fig. 8.

The success of the test hinged largely on accurate measurements of phase angle, and consequently two methods were developed for measuring this value and in addition, a rough check was secured from the synchroscope. Probably the simplest means of determin-

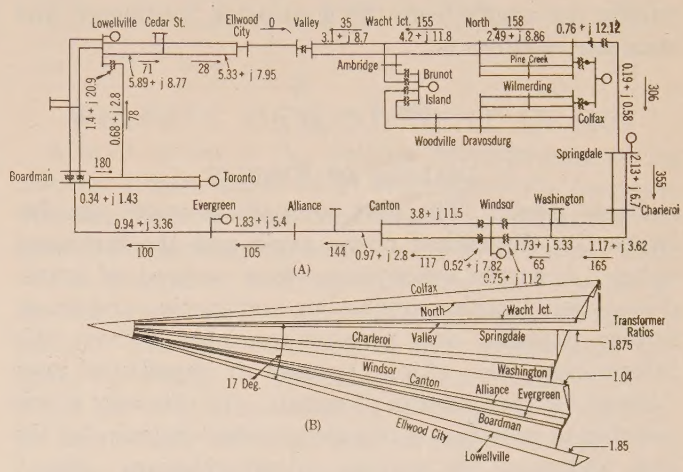

Fig. 7—Phase-Angle Calculations for Readings Taken at 6.00 p. m. on April 16, 1928

A. Schematic circuit diagram showing amperes and impedance per circuit in 66-kv. terms

B. Voltage vector diagram derived from the conditions in (A)

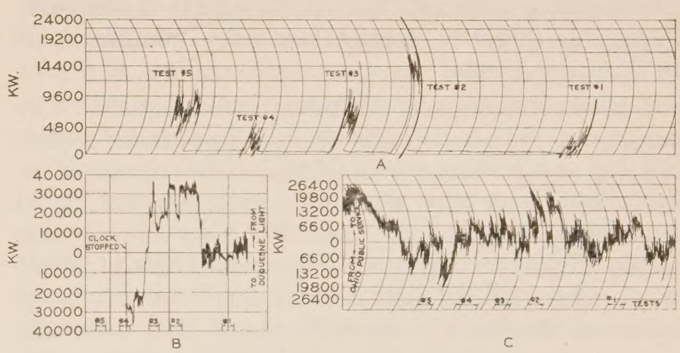

Fig. 8—Records of Power Flow Over Tie Lines

A. Kw. chart at Valley Substation on tie between Duquesne Light Co. and Pennsylvania & Ohio Power & Light Co.

B. Kw. chart at Colfax Station on tie between Dueuesne Light Co. and West Penn Power Co.

C. Kw. chart on Alliance circuit at Canton

ing the angle is by the three voltmeter method as shown on Fig. 6. Here the magnitude of the two system voltages is determined and the vector difference measured directly on the third voltmeter. Obviously, this scheme cannot be applied accurately to small angles and does not indicate lag or lead so apparatus was set up to use the wattmeter method. Briefly, this method consists of sending current through the current coil of a single-phase wattmeter supplied through a non-inductive resistance from the potential transformer on one

side of the breaker while the potential for the voltage coil was secured through a 90 deg. displacement transformer from a potential on the other side of the line breaker. Thus when the two line voltages are in phase, currents in the two elements of the wattmeter will be 90 deg. out of phase and the reading will be zero. This point can be accurately checked with the circuit breaker closed and the method is very sensitive for small angles. Fig. 6 shows the diagram of connections for the wattmeter method. An expression for determining the angles from the wattmeter, voltmeter, and ammeter readings is:

$$\text{Sin } \theta = \frac{W}{V I}$$

Analysis of Results

Phase Angle. The first comparison made was between the theoretical phase angle and the measured value. Accurate descriptions were secured of transmission line lengths, conductors, and spacing and transformer capacity and percent reactance. From this information, the ohmic values of impedance were derived for each section of circuit. In this way it was possible to construct a complete vector diagram for the loop and show the various voltage relations. Fig. 7 shows the results of one of the sets of readings for which the calculations show an angle of 17 deg. as compared with a measured angle of 19.6 deg.

On Fig. 8 is a reproduction of the recording wattmeter chart of interchange power at Valley Substation. There was considerable fluctuation and it is obviously impossible to get readings taken a few minutes apart to check accurately.

Equivalent Reactance. Another check was secured by comparing the actual total effective impedance around the ring as determined from a physical description of the apparatus with the effective impedance calculated from the readings on the test. Thus, on this test, one of the voltmeters indicated a vector difference of 22,800 volts with the breaker opened, and the wattmeter indicated 16,300 kw. resulting power flow when the breaker was closed. These quantities result in an effective impedance of 90.5 ohms as compared with a figure of 82.7 ohms derived from transformer and line characteristics.

These values of so-called "effective" impedance may be expressed as $\frac{Z^2}{X}$ and thus vary slightly from the true impedance. The reason for this is readily apparent when we consider that although the current caused by the quadrature vector voltage difference due to the phase displacement is equal to that voltage divided by the true impedance $\left(i.e., I = \frac{V}{Z} \right)$, this current is out of phase with the line voltage and must be multiplied by $\frac{X}{Z}$ to get the true power component.

Thus:

$$P = \sqrt{3}\, E\, I \cos \theta \qquad P = \text{Watts}$$

$$I = \frac{V}{Z} \qquad E = \text{Line voltage}$$

$$V = \text{Quadrature voltage (neutral terms)}$$

$$\cos \theta = \frac{X}{Z} \qquad X = \text{Total circuit reactance}$$

$$Z = \text{Total circuit impedance}$$

Hence:

$$P = \sqrt{3}\, E\, V \left(\frac{X}{Z^2} \right)$$

And:

$$\frac{Z^2}{X} = \text{Effective impedance}$$

The use of pure impedance to determine kv-a. would probably lead to error since any generator voltage regulators in operation would tend to maintain constant voltage magnitudes. Phase displacements are little affected by this action, however, and it is interesting to note that the closing of the tie breaker at Valley Substation and the resulting shifting of power flow had no effect on any of the power plant kw. outputs.

In a sense, the introduction of a quadrature voltage in a closed loop causes a circulation of power through each section, increasing or decreasing each of the previous loads by the same amount. This is illustrated in Fig. 8 where it is apparent that the same change in power appeared in the Valley-Ellwood tie, the Colfax-Springdale tie, and the Canton-Alliance circuit. In this manner it is possible to determine the voltage that must be introduced in a loop to produce any desired change in loading.

Table I was prepared as a summary of the results of the five tests showing the comparisons between calculated and actual values and other important features to be noted. Complete readings were not secured with which to calculate the phase angle for the first and last tests. The agreement between measured and calculated angles in the other three cases is quite close and the average effective impedance from test is only 7 per cent above the value derived from circuit characteristics. The variation in figures for kw. per degree is about 25 per cent above and below the average. These inconsistencies are not unreasonable when allowance is made for the fluctuating nature of the interchange power.

Application

Where systems of the same frequency are interconnected directly or through transformers to form a closed loop, the load control would probably take the form of a special type of regulator equipped for tap changing under load and connected for quadrature

TABLE I
EXHIBIT OF RESULTS DERIVED FROM INTERCONNECTION TEST

Test No.	Phase angle (degrees)				Total effective impedance $\frac{Z^2}{X}$, ohms		Interchange at Valley S. S.		Kilowatts per degree
	Measured								
	Vm.	Wm.	Average	Calculated	Circuit characteristics	From test	Kw.	To	(metered)
1	4.0	4.3	4.15	..	82.7	87.9	4,800	P & O	1157
2	20.3	18.8	19.65	17	82.7	90.5	16,300	P & O	830
3	8.0	7.5	7.75	9	82.7	80.9	7,200	P & O	930
4	4.3	3.2	3.75	5	82.7	86.0	3,600	D. L.	960
5	11.3	10.3	10.80	..	82.7	96.8	8,400	D. L.	778
				Ave.	82.7	88.4			931

action. Since the addition of a voltage at right angles makes a slight change in resulting magnitude, the power control could economically be combined with the ordinary voltage regulator to give complete flexibility. This apparatus would be very similar in construction and operation to the transformers which are designed for tap-changing under load and which have been developed in the last few years to a high degree of reliability. Thus the phase shifting regulator or transformer does not represent an entirely new piece of equipment but can be built and applied without extensive development work.

If voltage and reactive conditions are undesirable on either or both systems indicating the possible necessity for synchronous condensers, a motor generator set of the synchronous-synchronous frame shifting type might be used which would at the same time control power interchange. However, conditions would have to be unusual to warrant such an expense.

It is a well-known fact that a three-phase voltage regulator incidentally produces a phase shift and the application of two such devices in series will make possible the control of power and wattless kv-a. This scheme could be applied to low-voltage, medium capacity tie lines but probably is not economical in large applications. An installation of this type has been reported in operation on an extensive power system in Texas.

Where the interconnection is between systems of different frequency a motor-generator set is required, and power control can be secured by a frame shifter for the synchronous type or by use of the assynchronous machine if it is not necessary to maintain rigid phase relations.

In any event, the necessary range of phase shift can be readily determined by the method outlined and it should be remembered that this method of analyzing power flow problems and selecting equipment characteristics applies equally well to conditions within a system itself. Diversity of supply and differences in circuit characteristics may result in non-uniform loading and inefficient use of existing facilities. Conditions very likely exist where the installation of additional capacity could be obviated if inexpensive phase shifters could be applied.

WELDING DEVELOPMENT IN 1929

A brief review of the welding developments during the year 1929 prepared by a Committee of the American Welding Society gives considerable information in regard to the application of arc welding to structural work.

The number of buildings and structures erected by the use of arc welding materially increased during this period. The first statistics of this nature were prepared by Frank P. McKibben in July 1928, when he listed 100 structures consisting of bridges and buildings. In July, 1929, the total had increased to 138. The number of welded buildings alone jumped from 43 to 65—a 50 per cent increase.

Further demonstration of the reliability of welding as a method of fabrication was found in the results of a two-years' series of tests on welded joints conducted at the Rensselaer Polytechnic Institute. Conclusions based on these tests indicated that the application of arc welding to the construction of buildings was no longer in the experimental stage, and that such construction can now be made with complete safety and with entirely successful results.

Many interesting applications of welding to this type of construction were made during 1929, of which a few outstanding examples may be chosen as illustrations. Early in the year, an extension to the power house of the Haddon Hall and Chalfonte hotels of Atlantic City was completed quickly and quietly, without disturbing the guests of either hotel or the residents of the cottages in the neighborhood. This power house has a height of 134 ft. and is one of the tallest welded-steel building frames in the world.

A new type of arc welded steel floor has been developed which materially reduces the weight of the structure. It utilizes steel plates and structural steel beams. According to the American Institute of Steel Construction, it is better than any floor that has before been used and is capable of withstanding any service to which the floor may be subjected. It is described as being a solid steel deck which acts as a girder to prevent any torsional distortion of the building when subjected to wind or earthquake action.

The total cost of a floor constructed of 3-in. I-beams and 3/16-in. plates, covered on the top with cork tile and fireproofed on the underside, is estimated by the Institute to be a little over $1.00 per sq. ft.

Abridgment of

Power Transients in A-C. Motors

A Watt-Oscillograph Study

BY L. E. A. KELSO[1] and G. F. TRACY[1]

Synopsis.—*The purpose of this paper is to describe the application of the watt-oscillograph to the study of the performance of rotating a-c. machinery under transient conditions. Some typical transient cases are presented with a view to illustrating the possibilities of such an application. The analysis of a film taken with the watt-oscillograph yields not only power but current and power factor also. It is thus possible, for the case of sinusoidal voltages and currents, to determine the locus of the current vector as it changes from one position to another.*

The paper also describes the watt elements of the oscillograph developed for this study, with data as to the degree of accuracy that may be expected from them. An outline of the method of analyzing an oscillogram so as to obtain the performance curves and the current locus is also given.

I. The Watt Element and Its Use

1. *Introduction.* The watt oscillograph not only serves the primary purpose for which it has been developed,—namely, that of recording the instantaneous values of power in an a-c. circuit,—but in the case of sinusoidal voltages and currents, its records also permit of the determination of the magnitude and the phase relation of the current with respect to the voltage. This determination may be made for transient as well as steady-state conditions, and therefore the locus of the current vector as it changes from one position to another may be determined. Such an analysis has proved to be particularly applicable to the study of transient conditions in three-phase a-c. motors, as, for example, the behavior of a synchronous motor following a change of mechanical load. The changes in the magnitudes and in the phase relations of the currents in such transients take place relatively slowly, so that a reliable analysis may be made throughout the whole of the transient period. In cases where the duration of the transient is only a very few cycles, it is difficult to obtain reliable analyses by means of the watt oscillograph.

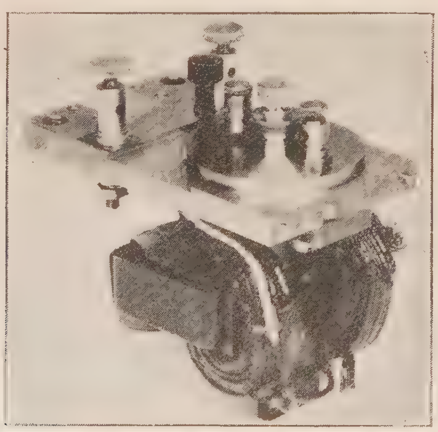

Fig. 1a—Illustration of Watt Element

2. *Description of the Watt Element.* Illustrations of a single-phase watt element as developed for these studies are shown in Figs. 1a and 1b. The magnetic circuit consists of 12 strips of 14-mil silicon steel, each strip being 1.43 cm. wide. The length of the iron path is 12 cm., and that of the air-gap, 0.07 cm. In order to minimize leakage flux and iron loss, the two exciting coils of 37 turns each are placed close to the air-gap as shown in Figs. 1a and 1b. The rated field current is 3.54 amperes (peak value) and the corresponding exciting m. m. f. is 262 ampere-turns (peak value). At this excitation, the flux density in the air-gap is approximately 4700 maxwells per sq. cm., and in the iron, it does not exceed 5000 maxwells per sq. cm. The volt—ampere load of the field winding at rated excitation is only 1.5 volt—amperes. In order to obtain sufficient deflection, the vibrators used are the Westinghouse supersensitive vibrators rather than the standard vibrators. These are oil damped. The full scale deflection of 4.5-cm. peak-to-peak is obtained with a field excitation of 3.54 amperes (peak value) and 0.0424 amperes (peak value) in the vibrator.

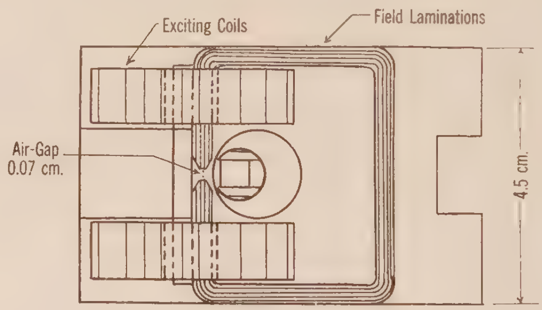

Fig. 1b—Plan View of Watt Element (from below)

Tests which were made to determine the accuracy of the instrument showed that the values of volt—amperes as calculated from the oscillograph records were within 1.4 per cent of the corresponding readings of meters placed in the same circuits, and that the maximum error in phase angles over the range from about 30 to 90 deg. was less than 4 deg. The accuracy with which the phase angle may be determined decreases, however, as the angle approaches zero, and in the neighborhood of zero the phase angle cannot be found within

1. Assistant Professor, University of Wisconsin.

about 10 deg. This is not a disadvantage in the case of three-phase power measurement as will be pointed out later. From these results it was apparent that with suitable ranges of field and vibrator currents, any errors caused by magnetic saturation and hysteresis in the iron circuit are no greater than those ordinarily incurred in measuring distances on an oscillogram.

3. *Interpretation of the Oscillograms.* If one watt element is connected in a single-phase circuit in which the voltage and current are sinusoidal, the power curve that it traces out will be a double-frequency sinusoid,

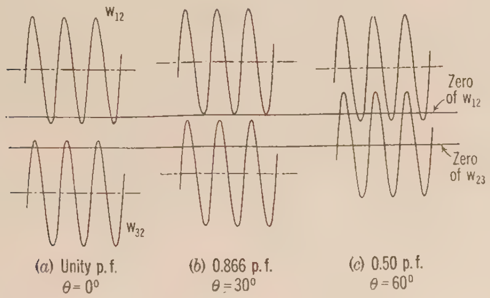

Fig. 2—Typical Three-Phase Power Curves

the peak value of which is proportional to the volt—amperes and the axis of which is displaced from the zero line of the power curve by a distance proportional to the average power. The phase angle between the current and voltage at any point on the curve is the angle whose cosine is equal to the ratio of the displacement of the axis of the power curve to its peak value.

If two elements are connected in a three-phase circuit in the same way that two wattmeters would be connected to measure three-phase power, (with the exception that it is preferable to reverse the potential connections of one element), two power curves will be traced out, each having the same characteristics as the single-phase curve. Typical power curves for three different power factors are shown in Fig. 2. The expressions for the two curves under balanced conditions are:

$$w_{12} = E\,I\,[\cos(\theta - 30 \text{ deg.}) - \cos(2\,\omega\,t - 30 \text{ deg.} - \theta)]$$
$$w_{32} = E\,I[-\cos(\theta + 30 \text{ deg.}) - \cos(2\,\omega\,t - 30 \text{ deg.} - \theta)]$$

where E is the r. m. s. voltage between lines, I is the r. m. s. line current, and θ is the angle between phase current and phase voltage. The double-frequency components of the two curves are in phase with each other and have the same amplitudes. The axis of the curve w_{12} is displaced *above* its zero line by a distance proportional to cos $(\theta - 30$ deg.) while the axis of the curve w_{32} is displaced *below* its zero line by a distance proportional to cos $(\theta + 30$ deg.). Therefore the phase angle θ, at any point on an oscillogram, may be found from either power curve. The value found from one curve may be checked against that found from the other, as the two values should be the same for balanced conditions. The angle between the current in the field and the voltage across the potential terminals in one element differs by 60 deg. from the angle between the current and the voltage in the other element. Therefore, when that angle in one element is in the neighborhood of zero degrees, so that it cannot be determined accurately as previously pointed out, the corresponding angle in the other element is in the neighborhood of 60 deg. at the same time, and may be determined accurately.

II. Typical Current Loci

The following section of the paper contains the results obtained from the analyses of the watt-oscillograph records of a few typical transient conditions in three-phase induction and synchronous motors. The performance curves and current locus corresponding to each case are shown. On each oscillogram are three curves, two of power and one of line voltage. In analyzing an oscillogram, the envelopes of the two curves were drawn and ordinates were erected at suitable equal intervals,—usually at every cycle on the voltage wave. The peak values of the double-frequency components of the power curves and their displacements from their respective zero lines were measured at each ordinate. In the following discussion, each oscillogram is accompanied by a tracing of the envelopes of the power curves showing the ordinates at which the measurements were made. In each case, the envelope of one curve has been shown by full lines and that of the other by dotted lines.

4. *Induction Motor Transients.* Power curves taken while rated load was being thrown on an induction motor and also while an induction motor was breaking down show a satisfactory check between the current

Fig. 5a—Rated Load Thrown on Synchronous Motor (Film 68)

loci as obtained from the oscillograms and the corresponding loci as obtained from ordinary load tests in which the points were obtained from meter readings. Lack of space does not permit including these cases in the abridged paper.

5. *Synchronous Motor Transients.* Figs. 5a and 5b show the power curves taken while rated load was being thrown on a 15-kv-a. synchronous motor. The load consisted of a d-c. generator as in the induction motor case. The excitation of the motor was adjusted so that the power factor was unity at full load. The power and current start to increase at about ordinate 6, and build up to values that are greater than the ulti-

mate steady-state values. After two or three oscillations, both settle down into their steady-state full-load values. The actual point of throwing the load on was at about ordinate 2 and not at ordinate 6. There is a dip in both the power and current curves which is caused presumably by a disturbance in the circuit which was used to excite the fields of both the motor and the d-c. generator, when the field circuit of the latter was closed.

The current locus in Fig. 5D corresponds to Fig. 5A.

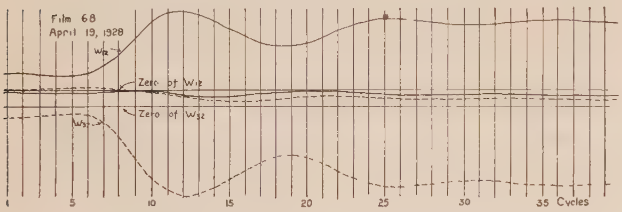

Fig. 5B—Power Curve Envelopes of Film 68

ordinate 1 is the position of the current vector I at no-load. It is seen that the locus has a small hook in it which corresponds to the initial dip in the current and power curves. The vector then travels out along

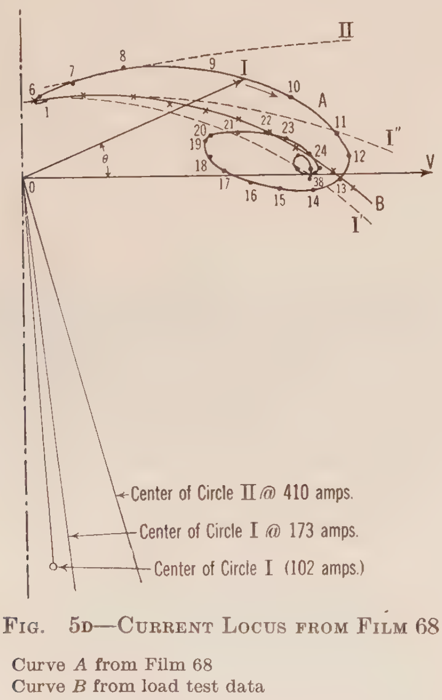

Fig. 5D—Current Locus from Film 68

Curve A from Film 68
Curve B from load test data
Circles I' and I'' are synchronous impedance circles
Circle II is a leakage impedance circle

a smooth curve through ordinates 7 to 12 as the load builds up. Its angular velocity is high in the vicinity of ordinates 8, 9, and 10, as indicated by the interval between these points. Maximum power is being drawn from the line at ordinate 12. It is apparent that the ultimate position of the current vector is in the vicinity of ordinate 38; *i. e.*, in phase with the voltage vector.

On the same diagram has been shown the corresponding current locus as computed from load test data. These points fall on the familiar circular locus, and since the excitation was adjusted for unity power factor at full load, the angle θ is nearly 90 deg. leading at no-load.

An explanation of the peculiar shape of the current locus in Fig. 5D may be given by using the same methods and approximations as those of the Blondel circle diagram. When the motor is running at no-load, its generated voltage vector is almost in phase opposition to the impressed voltage, while if the load is increased, the generated voltage vector lags farther behind its position at no-load. In the former case, the resultant voltage acting across the impedance of the armature is very small, while in the latter case it is quite large (assuming that the magnitudes of the generated and impressed voltages are approximately the same). The current in each case is proportional in magnitude to the resultant voltage and lags behind it by an angle of nearly 90 deg. The vector diagram of Fig. 6A shows the position of the vectors for five different steady-state loads. This diagram is for the case where the excitation of the machine is such as to give unity power factor at full load. The locus of the end of the current

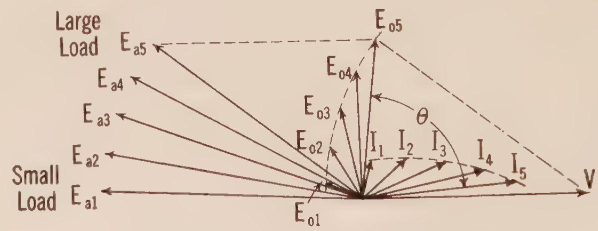

Fig. 6A—Vector Diagram of Synchronous Motor

vector is one of the constant-excitation circles of the Blondel diagram.

In Fig. 6A the vectors E_{a1} and E_{a5} represent the *excitation* voltage of the motor and not the *generated* voltage, for the magnitude of the latter is not constant but, because of armature reaction, varies as the load is changed. The relationship between any resultant-voltage vector and the corresponding current vector is therefore the *synchronous* impedance of the armature, and not the *leakage* impedance. It will be recalled that the use of the synchronous impedance accounts for armature reaction, because the magnetomotive force of the armature is assumed to be replaced by a fictitious reactance which is added to the leakage reactance of the armature, the combination of the two reactances being called the synchronous reactance. Thus in Fig. 6A, $I = E_o/Z_s$ and $\theta = \tan^{-1} X_s/r_e$; where Z_s is the synchronous impedance, X_s is the synchronous reactance, and e_e is the effective resistance. One of the constant-excitation current loci of the Blondel diagram is shown by circle I in Fig. 6B. This current locus corresponds to that shown in Fig. 6A. The center of

circle I is at point C which is distant from O by an amount equal to V/Z_s, and the angle between $O\,V$ and $O\,C$ is $\tan^{-1} X_s/r_e$. The vector V represents the impressed voltage.

Suppose that the armature reaction could be prevented in some way from changing the flux in the field poles. Such would be the case, for example, if either the field circuit or the damping grids had zero resistance so that the field flux were not allowed to change for au infinitely long time. This condition would mean that the additional fictitious reactance that replaces armature reaction is zero. The relation between the resultant voltage and the current is now E_o/z_a instead of E_o/z_s as it was before where Z_a is the transient or leakage impedance of the machine; and the currents, therefore, will be correspondingly larger and will not lag behind the corresponding resultant voltages by so large an angle because x_a is smaller than x_s. The current locus can now be shown to be another circle such as circle II in Fig. 6B with center C' on a line $O\,C'$

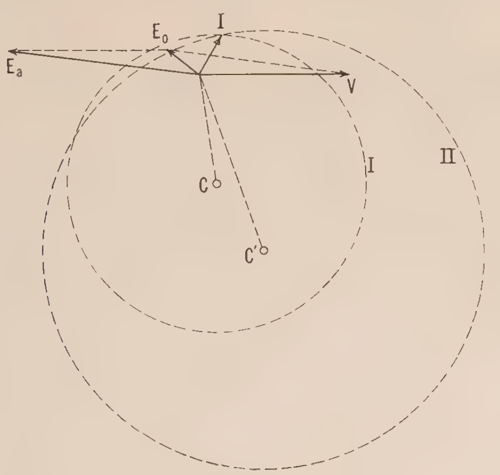

FIG. 6B—CURRENT LOCI OF SYNCHRONOUS MOTOR

which is displaced from the voltage vector by an angle $\tan^{-1} x_a/r_e$ and at a distance from O equal to V/z_a.

The two circles I and $I\,I$ of Fig. 6B represent two extreme conditions. Circle $I\,I$ is the locus of the current vector if the flux is prevented in some way from changing at all under the influence of armature reaction. Circle I is the locus if the flux readily follows the changes in resultant magnetomotive force. This latter locus is the one that would be traced out if the data from an ordinary load test are plotted; for, in such a test, the load is increased in steps and there is plenty of time for the flux to change to a new steady value between each step. This circle, then, might be thought of as the current locus when the load is very slowly increased. When full load is applied all in one step, however, the current at first will tend to follow circle $I\,I$ because the flux cannot change readily on account of the damping action of the field circuit and of the damping grids. Then, as the flux gradually yields to the effects of the armature magnetomotive force, the current vector will gradually move across to circle I.

Again referring to Fig. 5D, circles similar to those which have just been discussed are shown on this figure. Circles I' and I'' on Fig. 5D both correspond to circle I on Fig. 6B; *i. e.*, they are both synchronous impedance circles but the value of the synchronous impedance was measured by two different methods. The value of

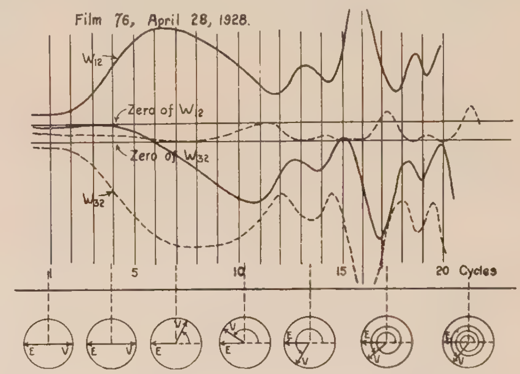

FIG. 8B—POWER CURVE ENVELOPES OF FILM 76

z_s for circle I' was obtained from short-circuit test data, while that for circle I'' was prepared from the zero power-factor test data. It is seen that the actual current locus as found from the load test falls between these two circles. Circle $I\,I$ of Fig. 5D corresponds to circle $I\,I$ in Fig. 6B, *i. e.*, its center was found by using

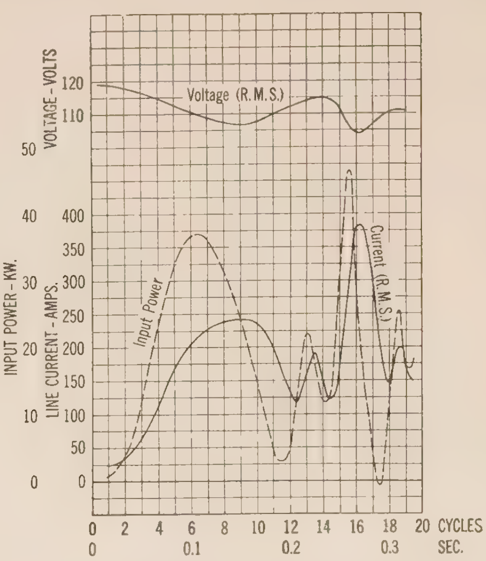

FIG. 8C—PERFORMANCE CURVES FROM FILM 76

15-kv-a., a-c. generator, 110–220-volt, 78.8–39.4-ampere 60-cycle, 1200-rev. per min.

the leakage impedance of the armature. The effect of the transient reactance of the field was neglected. The value of the leakage impedance was determined by the Potier method from the open-circuit and zero power-factor characteristics. It can be seen that the current locus for a rapidly increasing load actually tends to follow this circle at first, and then moves across to the other current locus as predicted in connection

with Fig. 6B. The field structure reaches the farthest point in its swing about ordinate 12, at which point, the voltage vector comes to rest, and starts to swing back again because it has overshot its ultimate position. During this time, the armature reaction has had time to change the field flux and bring the current vector completely over to its steady-state locus. However, as the field structure swings back again the flux is again slow in changing, this time in the opposite direction; and so the current vector swings down below its steady-state locus. After two or three oscillations the hunting of the field structure dies out and the flux and current settle into their steady-state full-load positions.

Figures 8A to 8E are for the case of a 15-kv-a. synchronous motor pulling out of step. The load was allowed to build up to a value which was beyond the maximum torque of the motor. In this case, a contactor mounted on the shaft of the motor was connected so as to momentarily short-circuit the voltage element at one point in each revolution of the motor shaft. As the machine was a six-pole machine, this momentary short circuit would occur once every third cycle on the voltage wave if the machine were running in synchronism. The discontinuities in the voltage wave can be seen in Fig. 8A. After the application of load, the intervals become greater than three cycles, indicating that the machine is slowing down. These marks afford a means of checking roughly the phase position of the field structure and of the excitation voltage, E_a, at the points at which they occur. If normal load had been applied, these marks would have shifted to a new steady position on the voltage wave, the distance between the old and new positions being the angle of coupling for that load.

A group of vector diagrams is shown beneath the curve in Fig. 8B, which indicates the phase position of the field structure (as shown by the excitation voltage vector E) at the points of discontinuity on the voltage wave. In these diagrams, the vector E has been made the reference vector because the points of short circuit were made at even revolutions of the motor shaft; *i. e.*, at integral numbers of cycles of E. Thus, at point 7 the motor shaft has made exactly two revolutions after passing point 1; *i. e.*, E has gone through exactly 6 cycles, but the applied voltage has gone through 6 cycles and about 60 deg. in addition.

By referring to the power curve in Fig. 8C it is seen that the power reaches its first maximum about point 7. The phase relation between $-E$ and V in this position is about 60 deg. The power does not reach its first minimum value until about point 12 at which the angle between $-E$ and V is about 180 deg. Then there is a small increase in power to point 13 after which it again passes through a minimum at point 14. The vector diagrams show the angle between $-E$ and V to be roughly 360 deg. at point 14, indicating that the rotor has dropped back a whole pair of poles and the power cycle is about to repeat itself. The second power cycle is similar to the first, the difference being that the power rises to a higher maximum value and the time of the power cycle is much less than that of the first cycle because the rotor is now slipping back at a greater rate. The most noticeable feature of this current locus is its departure from the circular locus of the Blondel circle diagram according to which the current should traverse a true circle (see circle I Fig. 6B) for this case.

III. Conclusion

The authors gratefully acknowledge the many suggestions given them by Professor Edward Bennett and Professor J. R. Price of the Department of Electrical Engineering, University of Wisconsin.

Will absolutely pure iron have infinite permeability and zero hysteresis loss? T. D. Yensen writing in the *Electric Journal* believes there is good reason to think so. Investigators have for years been trying to produce pure iron. Each thousandth of a per cent impurity extracted resulted in an iron of higher permeability and lower loss than previous irons.

Iron 99.85 per cent pure is obtainable on the open market. In the laboratory iron 99.95 per cent pure has been available for several years. But it is those last few thousandths of a per cent that matter and defy removal. Even small percentages of "impurities" have enormous effects, as indicated by two samples, one having a permeability of 20,000 and the other 60,000, a difference of about 300 per cent, the compositions of the iron differing only by about 0.004 per cent carbon.

The elimination of carbon and oxygen down to 0.01 per cent offers no great obstacles. The problem is made more difficult by the fact that methods for determining these elements with sufficient accuracy are either not available or if available, they require much time and great skill in operation.

Various methods have been tried for deoxidizing the electrolytic iron by means of elements that combine with the oxygen and after combining with it are precipated from the solution and can be removed either as slag or as gas, but none of them remove oxygen quantitatively unless a large excess is used.

Paradoxially the answer to the problem of removing oxygen seems to be to add carbon. If just the right amount of carbon is added to molten iron in a vacuum furnace, it will combine with the oxygen and the resulting carbon monoxide gas can be removed by pumping. The trick, of course, is to add just the right amount of carbon for if not enough is added there will be left some uncombined oxygen, if too much is added uncombined carbon will remain in the iron, either of which as pointed out above has large effects upon the magnetic properties of the iron.

Transoceanic Telephone Service—General Aspects

BY T. G. MILLER[1]
Associate, A. I. E. E.

Synopsis.—The extent of transatlantic telephone service and its growth since its inception in 1927 are outlined in this paper.

It is pointed out that at the present time 85 per cent of the world's telephones are included in the area served and about 50 calls are made per business day. Analysis is given of the calls with respect to distribution by countries, by time of day, and by kind of message. The volume of calls, the rates, and the percentage of uninterrupted calls are given. Plans for future extensions of the service are outlined.

COMMERCIAL telephone service between the United States and Europe was initiated January 7, 1927 over one radio circuit, using long waves (about 5000 meters) and with the circuit terminals at New York City and London, England. Two papers[2] were presented at the Winter Convention of the Institute in February, 1928, on the subject of Transatlantic Telephony, and these outlined the situation as it stood then, after one year's experience with this new telephone service.

There has been a rapid and consistent growth in both the scope and volume of this overseas telephone service, which has clearly demonstrated that such service has a permanent and important place in international communications. It is the purpose of this paper to review briefly the changes in the character and extent of the service that have been made since the presentation of the papers referred to and to consider certain general aspects of the service as now furnished.

The initial long-wave radio circuit has now been supplemented by three radio circuits which operate at short wavelengths ranging from approximately 12 to 50 meters and which terminate at New York and London. In addition to the European service, arrangements have been made for establishing telephone service early this year between the United States and points in South America by the use of a short wave radio telephone circuit with terminals at New York and Buenos Aires. These new short-wave systems are discussed in three papers to be presented at this meeting by Messrs. Bown, Oswald, and Cowan.

The whole of England and Scotland, Dublin and Belfast in Ireland, most of the important cities and countries in Europe, and one point in Africa, are now within reach of telephone users in the United States, Canada, Cuba, and Mexico. The number of points between which the service is available is continuously increasing, as new points and even whole new countries are added from time to time as the necessary arrangements are made. Very soon after the inauguration of the telephone service between New York and London, this service was made available to telephone users in all parts of the United States. Soon thereafter extensions were made to Canada, Cuba, and Mexico. In Europe the extensions have closely followed the development of the continental connections centering at London, which is still the European terminal of the transatlantic telephone circuits. Among the more important European extensions was the opening of service to France and Germany. The shaded areas on the map shown in Fig. 1 indicate those sections of the overseas world which could be reached by telephone from the United States, Canada, Cuba, and Mexico at the end of 1929. Twenty countries, with a population of about 400 million and with eighty-five per cent of the world's telephones, were included within the area served on both sides of the Atlantic. The next major development expected will be the connection to this network of a substantial part of South America by the inauguration of telephone service over the New York-Buenos Aires circuit mentioned above.

For the year 1929, the distribution of the transatlantic calls by countries at the European end was about as follows:

England, 52 per cent; France, 32 per cent; Germany, 8 per cent; other countries, 8 per cent.

Although the daily service period was limited at the start by the restriction of the hours for telephone use of the Rugby transmitting station in England, it later became possible to extend the hours so that in the spring of 1928 the service was available about 10½ hours each business day. As the demand for the service increased and additional channels became available to increase the reliability of the service at times when atmospheric conditions were unfavorable, still further extensions were made in the hours of service. The chart in Fig. 2 shows graphically the changes in the hours of service which have been made. Since September 10, 1929 the service has been available on a 24-hour day basis. The changes that were made in the hours of opening this service in the morning are due in part to changes in London and New York to the daylight saving plan.

The service is in greatest demand during those periods of the day in which the business hours in America and

1. General Manager, American Telephone and Telegraph Co. Long Lines Department, New York, N. Y.

2. K. W. Waterson and O. B. Blackwell. A. I. E. E. JOURNAL, April and May, 1928, respectively.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Printed complete herein.

Europe overlap, although the tendency of this traffic to peak in these hours is not as great as might be expected. It is an interesting fact that even with a time difference of five or more hours, which leaves only a few overlapping business hours, the hour by hour demand for the transatlantic telephone service displays quite the same characteristics as generally comparable long distance telephone traffic in this country. Fig. 3 shows the distribution by hours of the transatlantic traffic and sions in Europe or America. The initial rate of $75 was reduced to the present level on March 4, 1928 and this was, of course, responsible for some growth in business. The messages per day, averaged monthly, increased from 13 in February 1928 to 45 in May, only three months after the rate reduction, although part of this increase was due to additional points reached by the service during this period.

The volume of business offered in the European ser-

Fig. 1—Map Showing Areas Reached by Transatlantic Telephones During the Year 1929

for purposes of comparison the distribution of other person-to-person traffic originating at New York. The remarkably close agreement may be explained in part by the fact that the usual business hours in this country correspond to the afternoon and evening in Europe, at which times there seems to be the greatest demand for transatlantic telephone facilities for conducting business and for social conversations.

The basic rate from New York to London is at present $45 for three minutes with slight additions for extensions in Europe or America.

vice has grown rapidly. From a start of only a few messages each day in 1927, it has grown until during 1929 the average was close to fifty messages per business day. Fig. 4 shows this graphically. The largest number of messages handled in any one day to date was 139. Aside from the seasonal variations which usually result in a falling off of business during the summer, and the drop following the opening due to the falling off of calls placed partly out of curiosity, the trend has shown a consistent increase. Some of the factors

contributing to this, other than the changes in rates, are the improvements in transmission and speed of completing connections, the increase in points within reach of the service, the extension of service hours, and an increasing appreciation by the public at large of the value of this service.

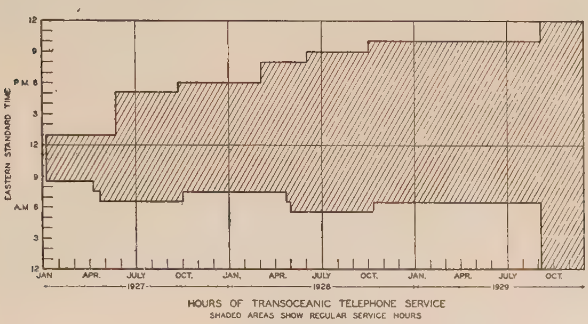

Fig. 2

As to the nature of the business handled, social calls seem to make up a large percentage of the transatlantic telephone traffic. The actual percentages of the business which may be classified as social, business, or otherwise, are as follows:

Social, 48 per cent; Bankers and Brokers, 27 per cent; Merchants, 4 per cent; Miscellaneous 21 per cent. It should be appreciated that there may be some inaccuracy in this classification, since it is largely based on the location of the called and calling telephones.

With connections as long as those involved in transatlantic service, and with circuits subject to the transmission variations inherent in radio, there is a likelihood that some atmospheric or other conditions will cause momentary interference to conversation. The

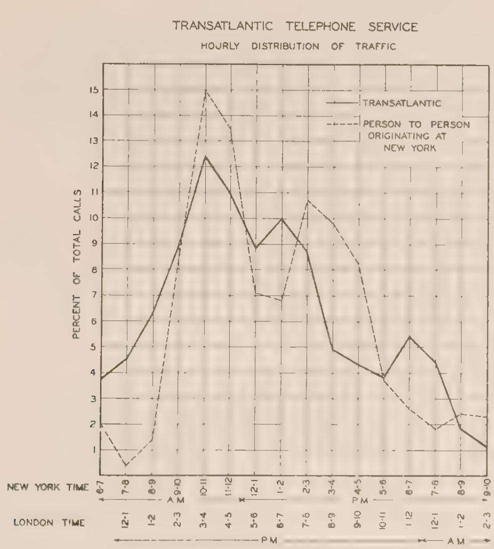

Fig. 3

results of transmission observations on New York-Great Britain traffic for the month of September 1929 are shown on Fig. 5. It will be noted that there were only about 5 per cent of the messages on which there were sufficient adverse reactions to result in less than 75 per cent of the elapsed time from beginning to end of the connection being chargeable.

As mentioned before, the scope of the transatlantic telephone service has been broadened by extensions from time to time to contiguous areas in both Europe

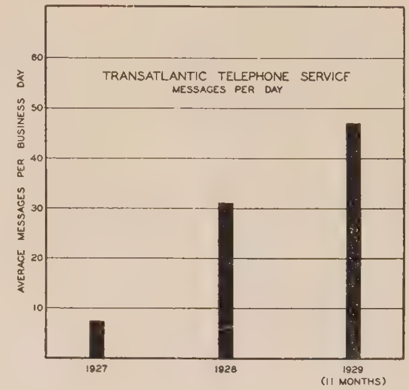

Fig. 4

and America. Further extensions by land lines can be expected to areas not now served, but it appears that in so far as the United States is concerned, because of the wide scope of the present land line system, the major extensions to new areas will, of necessity, be by means of new overseas services. Among these are the proposed telephone connection to South America and the ship-to-shore radio telephone service recently inaugurated. To strengthen further the ties already made, there is a comprehensive program under way which includes a transatlantic telephone cable and a second long-wave transatlantic circuit. Additional short-wave channels to Europe and South America may be added, if required by future developments of the business, and it is to be expected that telephone service to other countries will be established from time to time, as may be justified by the requirements for this form of communication.

The technical means to make this possible are now largely available, but, of course, other factors such as economic considerations must be taken into account.

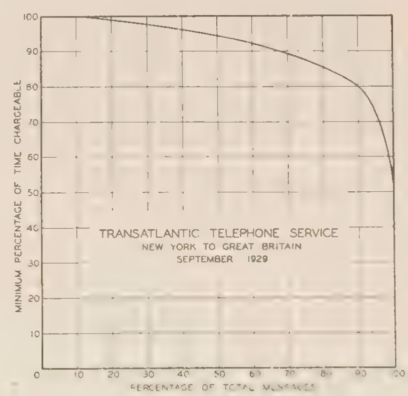

Fig. 5

While continuous and consistent progress is looked for, the ideal of a world-wide telephone service operating on a comprehensive and commercial basis and with a high degree of reliability is something which must be approached gradually and with patience.

Electric Welding by the Carbon Arc

BY J. C. LINCOLN[1]

Member, A. I. E. E.

Synopsis.—This paper discusses the butt welding of steel sheets by the carbon arc process. It explains first that autogenous welding is divided into two main classes, viz., gas and electric; that electric arc welding is divided into two classes, viz., metallic and carbon arc.

Gas and metallic arc welding in general require beveling of plates for butt welds while carbon arc welding does not. The controlling variables in carbon arc welding are (1) amperes in the arc, (2) voltage across the arc, (3) magnetic field about the arc, (4) atmosphere about the arc, (5) speed of feed, and (6) filling-in material.

Discussion is given of the effect of each of these variables of the resulting weld with special reference to the action of a magnetic field parallel to the direction of the arc upon the current in the arc and the effect of the atmosphere about the arc on the ductility of the resulting weld.

WITHIN the last few years, the fusion welding method of joining steel sheets has come into increasing importance. In some cases it has replaced the riveting method. In fact those vessels which carry fluid under the highest pressure and highest temperature *can be made only by the welding method.* For instance, it is impossible to make the large stills for cracking petroleum products into gasoline by the riveting method. In these stills the temperatures are of the order of 1000 deg. fahr. and the pressure of about 1000 lb. per sq. in. A large number of these stills has been welded and has been in satisfactory operation for years and a representative of one of the largest boiler-making concerns in the country stated recently that it would be impossible to make such a vessel by riveting.

There are three fairly distinct processes of welding steel sheets to each other, (1) the acetylene gas process, (2) the metallic arc process, and (3) the carbon arc process. In the acetylene gas process the edges of the sheets are melted by the oxy-acetylene flame and additional weld metal is melted between the sheets, thereby joining or welding them together. In the metallic-arc process an arc is drawn between a piece of wire and the surface of the sheets to be joined. The arc heats the surface of the sheets to a melting temperature and at the same time melts off a portion of the metallic electrode. This molten metal fuses with the surface of the sheets and thereby makes a weld. In both of these processes it is necessary in most cases to bevel the edges of the sheets so that the heating flame can fuse the surfaces at the bottom of the sheets. Fig. 1 shows a sketch of sheets ready to be joined and shows the beveling of the sheets which allows the gas flame or the metallic arc to fuse the bottom portions, thereby making possible a weld clear through the sheet.

The third process is the carbon arc process which is the subject of this paper. The use of this process does not require beveling the edges of the sheets which are to be joined.

The carbon arc process has the advantage of being able to melt clear through a sheet 1/4 or 3/8 in. thick without previous beveling. This is due to the fact that most of the heat in the carbon arc is developed on the positive terminal which in this case is the surface of the sheets to be joined. This excess of heat on the positive terminal produces a crater which is deep enough to penetrate through the sheets.

Fig. 2 is a sketch showing the cross section of the essential parts of the mechanism necessary to the use of the carbon arc. The lower sketch, Fig. 2, is a cross section of two plates butt-welded by the carbon arc process. The carbon arc process has the important advantage that the resulting weld is *more ductile* than the ordinary metallic arc weld.

Fig. 3 is a view of the welding head, the carbon electrode, the string reel, feeding mechanism, and general assembly. Fig. 4 is a view of the whole machine.

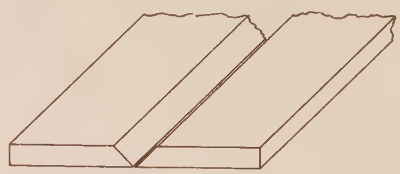

FIG. 1—SHOWING BEVEL REQUIRED FOR ACETYLENE OR METAL ARC WELDING

As seen in Fig. 2 the work is held in the machine by clamps on each side of the weld which are operated by compressed air. When it is desired to make a weld, the metal is rolled into the form of a tube, introduced into the machine with the seam midway between the clamps and when the seam is properly located, the clamps are dropped on to the metal to hold it rigidly in place.

The bottom of each clamp is formed of copper fingers which firmly grip the cylinder. Copper is used for the fingers on account of its high heat conductivity, so that while the weld is being made the intense heat of the arc will not fuse the fingers.

The operation is very simple. The arc is struck at one end of the seam to be welded. The welding head is moved along the seam by automatically controlled means and when properly adjusted the weld is made clear through the thickness of the sheets to be joined. When the head has arrived at the other end of the seam, the weld is completed.

1. The Lincoln Electric Company, Cleveland, Ohio.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Printed complete herein.

At this time, the two clamps are raised by pneumatic or hydraulic means and the welded cylinder, which may be pipe or part of a range boiler, or part of an unfired pressure vessel of any sort, is removed from the machine and the operation is repeated.

There is a number of variables which have to be adjusted to each other and to the work to be done in order to get the best results. The controlling variables may be mentioned as: (1) the amperes in the arc, (2)

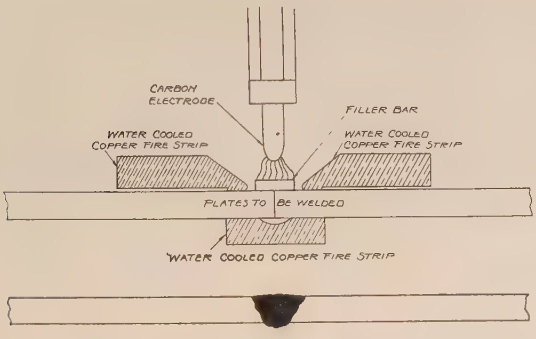

FIG. 2—DRAWING OF ESSENTIAL PARTS USED IN CARBON ARC WELDING

the voltage across the arc, (3) the magnetic field in the space occupied by the arc, (4) the atmosphere about the arc, (5) speed of feed, and (6) the material which may be laid along the seam to be joined to furnish added weld metal so that the cross section of the weld will be

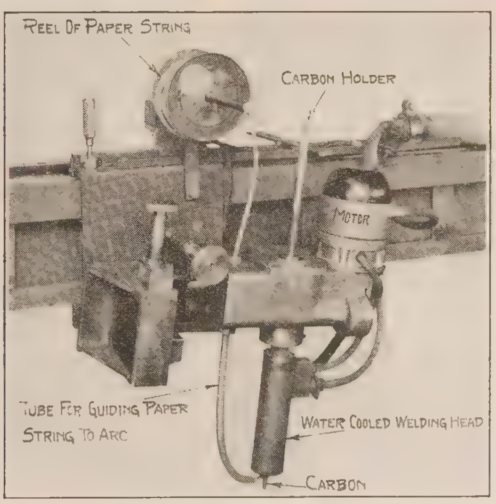

FIG. 3—CARBON ARC WELDING HEAD

somewhat greater than the cross section of the original sheets which are being joined.

The variables which occur in the resulting weld and which depend on the proper control of the variables mentioned above may be listed as: (1) the depth of the weld, (2) the width of the weld, (3) the tensile strength of the weld, and (4) ductility of the weld.

The carbon arc process which I am describing is called the "Electronic Tornado" process for the reason that the metal in the molten state is revolved by magnetic action. There is provided in the movable head a winding which produces a magnetic field whose lines are substantially parallel to the direction of the arc. This field accomplishes two purposes: (1) It produces a rotation of the material which is being melted by the

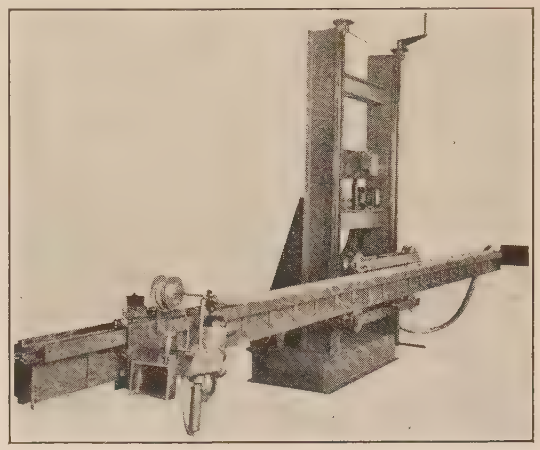

FIG. 4—COMPLETE MACHINE FOR CARBON ARC WELDING

arc, thereby mixing it more thoroughly, and (2) It provides a magnetic field which is in such a direction as to "stiffen" the arc and render it thereby less liable to trouble from parasitic magnetic fields.

Those who have had experience in arc welding know that the presence of parasitic magnetic fields causes a blow of the arc, especially at the end of a weld, which makes welding much more difficult than it otherwise would be, and by rendering the work more difficult is likely to interfere with its quality.

The reason why the magnetic field produces the

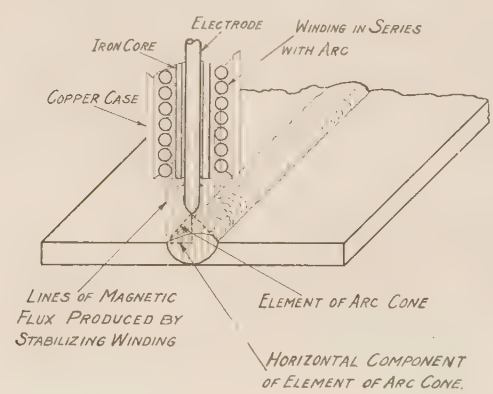

FIG. 5—DIAGRAM SHOWING WINDING FOR PRODUCING MAGNETIC FIELD

rotation of the melted material can be seen from Fig. 5. It is a fact that in any carbon arc the cross section of the arc is smaller at the carbon electrode than it is at the work, or in other words, the arc is cone-shaped, the small end of the cone being at the carbon electrode. With a cone-shaped arc there is a component of current at right angles to the axis of the arc. This component of current is acted on by a magnetic flux parallel to the axis of the arc which produces rotation. Experience

shows that this rotation causes a more perfect mixing of the material which is being melted from the edges of the sheets which are being joined.

The action of the controlling variables on the resulting weld will be commented on below in the order in which they were given.

Current. The amperes in the arc in general determine the depth of the weld. This is what would be expected on account of the fact that the heat developed at the positive terminal of the carbon arc is equal to what is called the "anode drop," multiplied by current in amperes. This "anode drop" can be taken as about 12 or 13 volts and this multiplied by the amperes in the arc gives the watts and therefore, the heat developed at the immediate surface of the sheets which are being welded. The so-called "anode drop" is practically independent of the current; therefore, the heat developed and consequently the amount of metal melted will depend substantially on the amount of current used. Table I gives thickness of metal, amperes required, volts across the arc, and speed for butt welds.

TABLE I

CURRENT, VOLTAGE, AND SPEED IN BUTT WITH THE CARBON ARC

Thickness	Current amperes	Voltage across arc	Speed ft. per hr.
No. 14 0.078 in.	350	25	150
No. 12 0.109 in.	425	30	110
No. 10 0.140 in.	425	30	95
3/16 in.	450	32	75
1/4 in.	450	32	60
3/8 in.	550	35	40

Voltage across the Arc. The feed of the carbon electrode is controlled automatically by a magnetic

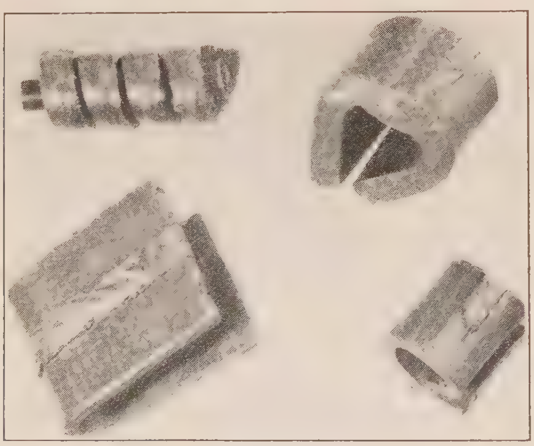

FIG. 6—SAMPLES OF STEEL WELDED AND DEFORMED WITHOUT FAILURE OF WELD

clutch and the carbon is continually rotated in order to preserve a symmetrical point on the carbon. The magnetic clutch operates when the voltage across the arc is greater or less than the predetermined amount and the feeding mechanism is thus brought into action. By this means the voltage across the arc is automatically maintained. When the voltage across the arc is high, the arc is long and the width of the weld is greater than it is with a short arc. Another effect which exists is that with a long arc the total heat developed in the arc is greater than it is with a shorter arc and consequently there is some additional heat supplied to the surfaces which are being melted, though from a practical standpoint increasing the length of the arc does not greatly increase the effective heat.

Field Strength. The stabilizing magnetic field is produced by the winding shown in Fig. 5. The welding

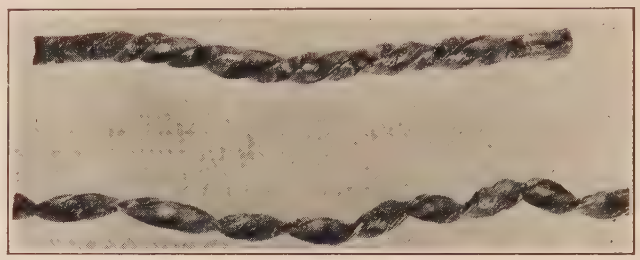

FIG. 7—WELD METAL TWISTED WITHOUT FAILURE

current passes through this winding and the field is proportional to the current. About seven turns are ordinarily used. With 400 amperes this gives 2800 ampere-turns.

The Atmosphere around the Arc. The atmosphere around the arc is of controlling importance in determining the ductility of the resulting weld metal. Experience has determined that the oxidizing action of the

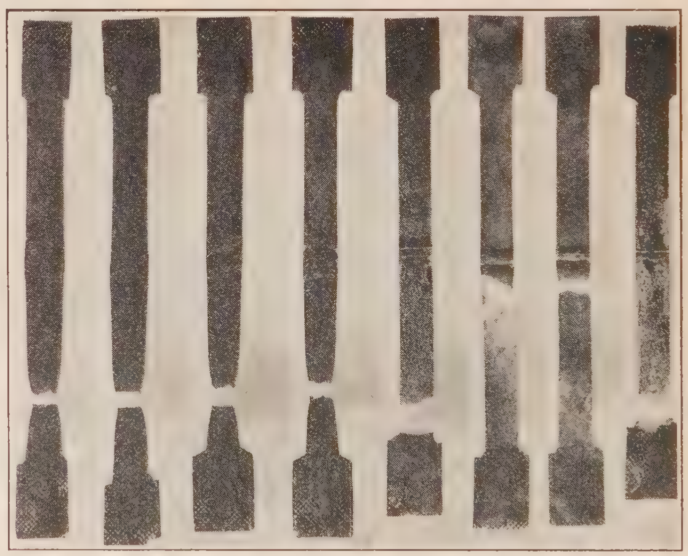

FIG. 8—WELDED STRIPS WHICH FAILED UNDER TENSION OUTSIDE OF THE WELDS

atmosphere is the cause of the lack of ductility in the ordinary metallic arc weld and in the carbon arc weld without means of controlling the atmosphere. In the particular head which is being described, a means is provided for controlling the atmosphere about the arc which consists in feeding paper string continuously into the arc. This string burns as it approaches the arc and produces an atmosphere having CO^2, possibly CO and some hydro carbons.

Speed of Feed. The speed of feed of the head or of

the arc along the seam to be welded is controlled and varies from 6 in. to 3 ft. a minute depending upon the thickness of the weld to be made and the amount of current used, etc. As would be expected a high speed produces a shallow weld with a given current. A lower speed produces a deeper weld. The speed of feed and the current and the thickness of the weld have to be so adjusted in reference to each other that the weld will penetrate to the desired depth. See Table I.

Feed-In Material. It is possible in general to make a weld which is stronger than the parent metal. In order to produce this result usually additional fill-in material is placed along the seam which is being welded so that after the weld is completed, its cross section will be about 20 per cent greater than the cross section of the parent metal. If desired special alloy fill-in material, such as nickel steel, may be used to increase the strength of the weld.

It is likely that the art will grow toward the decrease of the amount of added metal because the only reason for adding 20 per cent to the thickness of the weld as compared to the parent sheet is to be certain that the strength of the weld is greater than the strength of the parent sheet. Probably five years from now 5 per cent added material will be considered sufficient to insure greater strength in the weld than in the parent metal.

The welds made by this carbon-arc process are very ductile and strong. Figs. 6, 7, and 8 show test pieces which demonstrate these points. Fig. 6 shows three pieces of ½ in. steel butt-welded with the addition of 20 per cent of soft steel. These pieces were bent cold after welding as shown. No failure of the weld occurred. In the upper left corner of Fig. 6 is a strip of weld metal twisted around a pipe. In Fig. 7 are shown two strips of weld metal twisted cold without failure. Fig. 8 shows a number of sample strips of steel which were welded at their center. They were broken by tension and in every case the break occurred outside of the weld.

An Ultra Violet Light Meter

BY H. C. RENTSCHLER[1]

Non-member

***Synopsis.**—An instrument for measuring ultra violet radiation is described in this paper. The general plan of the meter is explained and a description of a small portable instrument is given. By means of proper choice of cells, as described in the paper, radiations of different desired frequencies may be measured.*

* * * * *

SUNSHINE and fresh air have long been recognized essential for good health in man as well as for animals and plants. It is now well known that this beneficial effect from sunshine is in large part due to radiation from the sun which is not visible.

By passing the light from the sun through a glass prism, rays of different color are separated, producing the well-known result called the spectrum. These various colors differ from each other in wavelength only. Thus red light has a wavelength of about 6000×10^{-8} cm., while violet light has a wavelength of about 4000×10^{-8} cm., with the intermediate colors having wavelengths between these two values. By suitable means of detection it can be shown that in the spectrum so obtained there is radiant energy of wavelength longer than the red, known as infra red or heat rays. Similarly we have radiation of wavelength shorter than the violet. This latter region is known as the ultra violet.

Due to the absorption by the atmosphere around the earth, the short wavelength limit in the sun's rays is about 2950×10^{-8} cm. Furthermore, due to varying atmospheric conditions and seasonal variations, this short wave end of the sun's radiation is so variable in intensity that for practical applications it is a rather unreliable source of ultra violet light. Artificial ultra violet light is now extensively used in medical treatment of certain ailments, for the production of vitamines, for bringing about certain chemical reactions (a field known as Photo Chemistry) and for many other purposes. For a systematic study of the effects so produced, a practical device for measuring the intensity and quantity of the light used is evidently of great value in determining a quantitative relation between the light used and the effect it produces.

The methods which in the past been have used for measuring or estimating intensities of ultra violet light may be classed as follows:

1. *Chemical.* Here the light generally produces certain color reactions in the compounds used and the intensity is gaged by the change of color and the time of exposure.

2. *Thermal.* The radiation is allowed to fall upon the surface of a body and the temperature change produced is used to indicate the radiant energy received. The thermo pile, the radiometer, and the bolometer are illustrations of this type of instruments.

3. *Photometric.* The intensity of fluorescence pro-

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Printed complete herein.

duced when the ultra violet light falls upon certain substances is compared photometrically with a standard light source.

4. Electrical. This method is based on the phenomenon known as the photoelectric effect where an electric current is permitted to pass between two electrodes in a vacuum or a gas, by letting the light fall upon one of the electrodes. Most metals show this effect only when illuminated by light of very short wavelength; that is, in the short ultra violet end of the spectrum. The current which can be produced in this way is very small and consequently requires either a very sensitive current measuring instrument such as a galvanometer or an electrometer, or an amplifier such as is used in radio together with less sensitive meters.

None of these devices as described are really suitable where simplicity of operation and portability are essential. It is the object of this paper to show how these difficulties are readily overcome by the use of a simple device. The operation is readily understood from the following description.

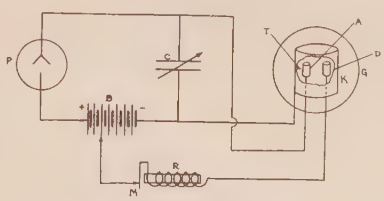

Fig. 1—Ultra Violet Light Meter Circuit Diagram

In the accompanying diagram, Fig. 1, a battery B charges the condenser C at a rate determined by the photoelectric current produced in the cell P when light falls upon the cathode of the cell. Heretofore this rate of charging of the condenser or in some cases the reverse effect,—namely the rate of discharging of the previously charged condenser,—was measured by means of an electroscope or electrometer. The simplicity of the scheme to be described here depends upon the substitution of a specially designed glow tube, which we shall call a "glow relay tube," indicated by G in the diagram in place of an electrometer.

This glow relay tube has an iron or other suitable metal cylinder about an inch in diameter and from one to one and a half inches long for cathode K. There are two anodes; one shown by A which we shall call the starting anode, and a second anode D which we shall call the main anode. The anode A preferably consists of thorium metal.

A small iron or nickel wire T, welded to the cathode, is so placed that it gives a short gap between the cathode and the starting anode A. The exact positioning of this starting tip with reference to the two anodes has an appreciable effect upon the sensitivity of the tube.

In operation, the main anode D is connected to the battery B through a relay R such as is used in telephone service for registering the number of calls. The voltage between the anode D and the cathode K is kept below that normally required to start the discharge. When the light falling on the photoelectric cell P charges the condenser C to such a potential that a discharge takes place between K and A, the cathode resistance of the glow tube is broken down and a current flows between the main anode D and the cathode. This operates the relay, pulls the armature over, registers the count and at the same time, opens the main circuit at M. Simultaneously the condenser is discharged. The light falling on P again charges the condenser C to the breakdown potential between T and A when the discharge is repeated. Thus it is clear that the intensity of the light falling on P, which is effective in producing photoelectric action, is proportional to the rate at which the counter registers and the total quantity of effective light which has fallen on the cell is proportional to the total number of discharges registered by the counter. In some cases it is desirable to use a sensitive relay for R which in turn closes and opens a separate circuit which operates the counter or other recording or operating device. By means of this device, it is possible to measure photoelectric currents of the order of a thousandth of a microampere or much less with as great ease as we now measure electron emission currents by the use of milliameters.

The next question that confronts one in the measurement of ultra violet light is the use of a cell suitable for the particular problem at hand. It so happens that photochemical reactions, or the response of the human system to ultra violet light radiation, etc., is limited to a definite region of the spectrum and that different reactions require different wave bands. By the selection of the proper material for the photoelectric cell, a cell can generally be found which will not respond to light of longer wavelength than that which is effective for the particular reaction. Light of wavelength shorter than that which produces the desired effect for the particular reaction can be prevented from reaching the photo cell by the use of suitable light filters. In some cases this can very conveniently be accomplished by using the proper kind of glass in the construction of the cell. In this way a very satisfactory intensity or quantity measuring device can be made by combining the proper photoelectric cell with suitable filter with the scheme outlined above. To illustrate this point, for the prevention and cure of rickets, the medical profession has fairly definitely established the useful wave band of light between 2800×10^{-8} cm. and 3200×10^{-8} cm. The curve of relative sensitivity for different wavelength as given by Hauser and Vahle[2] is shown in Fig. 2.

We have found that if uranium metal is used as the active material of the photoelectric cell, the cell will not respond to light of wavelength longer than about 3200×10^{-8} cm. as can readily be shown by interposing ordinary window glass between the source of the ultra violet light and the cell. Again, by using a suitable

2. *Vergl. Strahlentherapie,* Vol. 13, 1921, p. 41.

glass for the container of the cell, such as Corex D, only a very inappreciable amount of light of wavelength shorter than 2800×10^{-8} cm. will reach the active material of the cell. We thus have a device which measures very well the useful radiation of the ultra violet light in the region of wavelengths beneficial for this particular use.

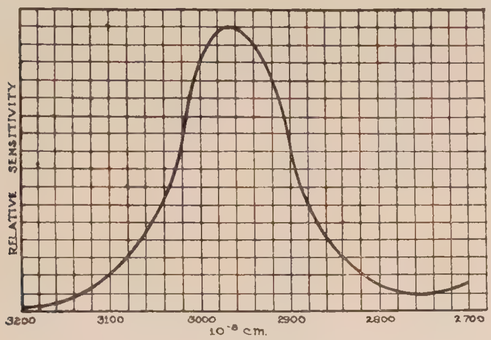

FIG. 2—ERYTHEMA CURVE ACCORDING TO HANSEN AND VAHLE

If the entire ultra violet region below 3200×10^{-8} cm. is to be measured, the cell container is best made of quartz instead of this special kind of glass. If the region of wavelength below about 3700×10^{-8} cm. is to be measured, we find metallic thorium serves very well for the active material of the cell. And again, if it is desired to measure light from blue into the ultra violet, the metal cerium serves admirably for the cathode of the photo cell.

The details followed in the construction of the cells

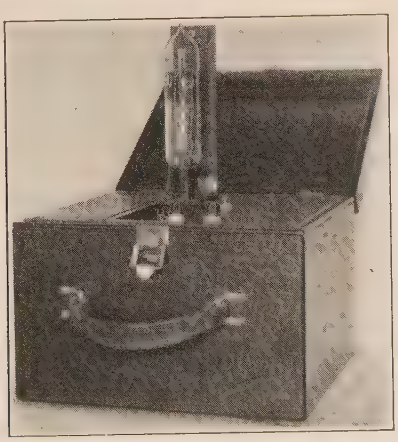

FIG. 3—PORTABLE ULTRA VIOLET METER WITH PHOTO CELL EXPOSED IN OPERATING POSITION

are omitted here for obvious reasons. These are of sufficient interest and will be described elsewhere.

The indicator complete, Fig. 3, is built into a case $10\frac{1}{2}$ by 12 by 9 in. The photoelectric cell is hinged on a door so that it can be set at different angles to allow the light to fall directly on the cell. When not in use, the cell folds into the case and the door protects it from being damaged. The electromagnetic counter that registers the indications is mounted inside the case. The 180 volts of B batteries are inside the case and can be replaced by removing the top panel. As the current through the photocell is very small, all parts of the circuit have to be highly insulated.

To operate the indicator, it is only necessary that the ultra violet rays fall on the cell. The number of counts in five or ten minutes gives the amount of the ultra violet radiation. For bright sunlight there will be approximately one hundred counts in five minutes. For half this intensity of light, there will be fifty counts.

The indicator alone is for measurements and tests of fairly short duration, such as treatments of food stuffs, testing of glass, and medical treatments. For continuous operations, a graphic meter that records the counts is attached. In this case, the electromagnetic counter

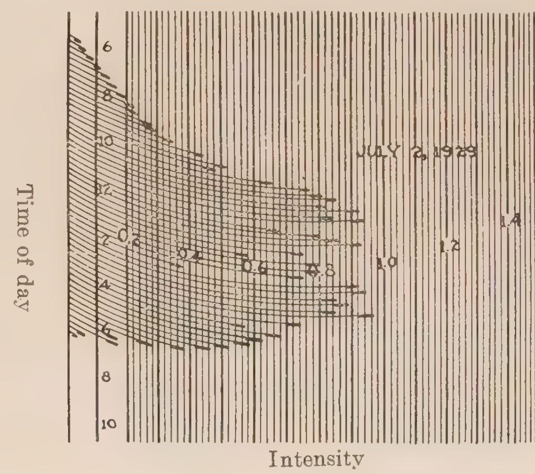

FIG. 4—GRAPHIC CHART RECORDING ULTRA VIOLET LIGHT IN SUNLIGHT ON JULY 2, 1929

is omitted from the indicator and the graphic meter operates from the contacts of relay R, Fig. 1. The graphic meter is the impulse type, that is, each count of the indicator notches up the pen of the recorder. The pen is automatically reset to zero every five minutes. The graphic meter gives a continuous record of the counts that occur in five minute intervals. Fig. 4 shows a chart taken of sunlight on July 2. The midday variation in ultra violet shown on the chart was due to its absorption in passing clouds.

The indicator alone is self contained and operates from the B batteries in the case. The graphic meter operates from a 110-volt light circuit and will give a continuous record for thirty days.

In conclusion it apears that by the combination here described we have a simple and at the same time a reliable method for measuring the ultra violet light as may be used for various purposes of application.

Abridgment of

Low-Voltage A-C. Networks of the Standard Gas and Electric Company's Properties

BY R. M. STANLEY[1] Fellow, A. I. E. E. and C. T. SINCLAIR[2] Member, A. I. E. E.

Synopsis.—The low-voltage a-c. network utilizing secondary network protectors has been adopted by five properties of the Standard Gas and Electric Company for service in areas of high-load density. The system has been applied to cities of the second class and smaller, although load density in certain cases is high. Each individual installation was made after a specific study of conditions involved.

Underlying principles on which all of the designs are based are: (1) Primary supply at generator voltage (11-kv. or 13-kv.), (2) omission of feeder regulators, (3) simplified transformer vault design with barrier wall between primary and secondary equipment, (4) high-reactance transformers, usually inherent, (5) use of secondary network protectors, (6) three-phase four-wire secondaries, (7) use of 250,000-cir. mil. secondary mains (or smaller) forming a solid grid without fuses.

The operating experience of the installations made thus far has justified their application. The use of the system in other areas will be considered in future planning.

* * * * *

THE low-voltage a-c. network has come into general use for distribution in the medium sized and larger cities. There are two general reasons for this; first, the high standard of service rendered, and second, the economies resulting.

The high standard of service, both from a standpoint of continuity and regulation, is in a broad sense the result of the principle of a secondary grid fed by a number of primary feeders. Primary faults are isolated by automatic switching. Secondary faults clear themselves. Hence, a failure of either portion of the system does not affect the service rendered.

As there is a strong tendency toward higher voltages, the regulation of the primary feeders is usually negligible. The regulation of the secondary grid is good because of the parallel paths and multiple feeds at the intersections of the grid. These principles are well known and have been discussed at length through the medium of the technical press.

The economies resulting from the application of network principles usually lie in the elimination of the substation by utilizing the generation voltage. Further saving is made in substation operating forces. Improvement in system efficiency is often apparent by use of higher distribution voltage and saving in transformer core loss during light-load periods.

In the past few years great improvement has been made in network equipment and failures of switches to operate correctly are now very infrequent. This is strikingly evident from the fact that out of over 34,000 service operations of the switches installed on the Pittsburgh network, only 18, or about 0.05 of 1 per cent, were not correct. Service was unaffected by these incorrect operations.

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Presented at the Great Lakes District Meeting of the A. I. E. E., Chicago, Ill., Dec. 2-4, 1929. Complete copies upon request.

Networks of Standard Gas and Electric Properties

Five of the larger properties of the Standard Gas and Electric group have adopted the low-voltage a-c. network for distribution in the business district of the cities served, namely Minneapolis, St. Paul, Oklahoma City, Louisville, and Pittsburgh.

Load Density

The load densities in these cities is as follows:

Minneapolis	34,000 kv-a. per sq. mi.
St. Paul	52,000 " " " "
Oklahoma City	47,000 " " " "
Louisville	20,000 " " " "
Pittsburgh	90,000 " " " "

Design Features

In the design of all the networks certain broad principles were followed. These are as follows:

(a) Primary supply at generator voltage.
(b) Omission of feeder regulators.
(c) Simplified transformer vault design.
(d) High-reactance transformers, usually inherent.
(e) A system with secondary network protectors.
(f) Three-phase four-wire secondaries.
(g) Use of 250,000-cir. mil, secondary mains, and smaller, forming a solid grid without fuses.

(a) Supplying the network at generator voltage from generating stations eliminated substation construction. In certain cases, feeders were also run from substations for added flexibility or as an initial step. In other cases, use was made of the existing 4-kv. substation capacity for network purposes.

(b) It was decided to omit feeder regulators where possible after an analysis of the system voltage conditions was made. When higher voltages are used for distribution, the primary voltage drop is usually not a limiting factor except where very long cable runs are necessary. Where the network supply voltage can be

varied throughout the day, feeder regulators may be omitted, especially if the primary cable runs are relatively short.

(c) A simplified vault design has been developed with a material reduction in the amount of cable work required and a fireproof barrier wall separating the primary and secondary equipment. This design is described in detail later in this paper.

(d) Transformers with 10 per cent reactance are generally used. This reactance is preferably made inherent. Subsequently in the paper a discussion of the value of this transformer design will appear.

(e) The system utilizing network protectors was adopted because of the increased measure of protection afforded to the low-voltage network and to service from the network, since this protective device is nearest to the network. By its use, segregation of potential trouble in transformer vaults, in transformers themselves, and in primary and secondary connections in transformer vaults is accomplished.

(f) The three-phase four-wire secondary offers a universal system whereby power and lighting loads can be served from the same secondary mains. There have been some objections to 199 for power voltage, but when difficult situations were encountered these objections have been met by the use of boosters.

(g) Relatively small secondary mains, 250,000-cir. mil and smaller, were adopted as a result of cable burning tests which indicated that larger cables were more difficult to clear in event of a secondary fault.

TABLE I
GENERAL CHARACTERISTICS OF STANDARD GAS & ELECTRIC NETWORKS

Subject	Minneapolis	St. Paul	Oklahoma Gas & Electric Co.	Louisville Gas & Electric Co.	Duquesne Light Co.
Area of network present, sq. mi.	0.57	0.125	0.10	0.50	0.50
Present load in network area, kv-a.	19,300	6,500	4,700	10,000	45,000
Kv-a. per sq. mi.	34,000	52,000	47,000	20,000	90,000
Load on network, end of 1929, kv-a.	9,100	1,500	5,800	2,300	22,000
Percentage light and power	Light 70 Power 30	Light 60 Power 40	Light 60 Power 40	Light 52 Power 48	Light 56 Power 44
Number of transformer banks	13.2 kv. 3 ϕ—16 13.2 kv. 1 ϕ— 1 4 kv. 1 ϕ—23	4 kv. 1 ϕ—20	13.2 kv. 3 ϕ— 9 13.2 kv. 1 ϕ—21	13.2 kv. 3 ϕ—16	11 kv. 3 ϕ—102 11 kv. 1 ϕ— 43 4 kv. 1 ϕ— 43
Ratio installed capacity to peak load	2 to 1	3 to 1	1.6 to 1	2.04 to 1	2.68 to 1
Primary voltage	13,200 4,000	13,200 4,000	13,200	13,200	11,000 4,000
Number of primary feeders	2 at 13.2 kv. 2 at 4 kv.	3	3	2	7 at 11 kv. 8 at 4 kv.
Source of supply	2 substa.	2 substa.	1 substa.	Gen. sta.	11 kv. gen. sta. 4 kv. 2 substa.
Feeder regulators	None	Regulators[1]	None	None	None
Secondary voltage[2]	Lt. 115/199 Pr. 230[2]	120/208	120/208	115/199	115/199
Secondary grid	Fused	Sectionalized by fuses[3]	Solid	Solid	Solid
Transformer sizes kv-a.					
13.2 kv. 3 ϕ	500 & 300	....	300	300 & 500	....
13.2 kv. 1 ϕ	150	....	100	....	....
11.0 kv. 3 ϕ	....	....	....	....	500
11.0 kv. 1 ϕ	....	....	....	....	100
2.4 kv. 1 ϕ	200, 150, 100	100	....	....	100
Voltage rating of transformers	13,800–120/208 2,400–120	2,400–120	13,800–120/208	13,200–115/199	11,500–120/208 2,400–120
Transformer impedance	5% inherent + 5% external reactance shunted by fuse	4% inherent	10% inherent	10% inherent	10% inherent on 11 kv 4% inherent + 6% external reactance on 4 kv.

Notes:—
1—Three single-phase regulators on each feeder; compensators not interconnected. These regulators were in use on the old radial system.
2—All secondaries are three-phase, four-wire except the power secondary in Minneapolis which is three-phase, three-wire connected through auto-transformers.
3—To be operated with sectionalizing fuses until sufficient short-circuit current is available to make the fuses unnecessary.

When required, two sets of mains can be installed, each in a separate duct. This, of course, requires an additional duct, but these ducts are frequently available because of the elimination of numerous cables on systems being replaced. Secondary grids are not fused and expensive servicing of fuses eliminated and cost of fuse boxes is thus saved.

The General Features of the Cities Served

Minneapolis has installed a network operating at both 13 and 4 kv. The 4-kv. is used primarily to employ the existing capacity at that voltage. All new load will be taken at 13 kv.

The St. Paul network utilizes 4-kv. in its initial step.

Fig. 1—Map Showing Six Sections of Pittsburgh Network

Again we find this voltage utilized because of the spare capacity available. It is expected that 13-kv. will be the ultimate distribution voltage.

The problem of conversion to the network in Oklahoma City was rather clean-cut, in view of the fact that the previous system was entirely overhead. When it was decided to place the system underground, the network was adopted to being best suited to local conditions; 13-kv. was adopted as the best voltage.

Louisville utilizes 13-kv. as its primary supply voltage. Here, there was no 4-kv. spare capacity available so all new cutover and all new load will be taken at 13 kv.

In Pittsburgh we find both 11 and 4 kv. available as the supply voltage although new load is taken chiefly at 11 kv. Attention is called here to the six-section scheme whereby the network that is supplying the downtown district is divided into six small areas (see Fig. 1.) Another fact peculiar to Pittsburgh is the extreme flood conditions met, and this requires submersible type equipment throughout.

All of these systems employ a three-phase, four-wire secondary taking both light and power from the same mains. The equivalent of 10 per cent impedance transformers are used, the impedance being usually inherent.

Economic Justification. In all of the network installations mentioned an economic study was made to determine the relative costs of the network and other systems. By way of example, the results of the Louisville study are given in the following table:

	Type of System	Relative cost based on three 5-yr. construction programs including carrying charges
1.	4-kv. radial from existing substation	1.10
2.	4-kv. radial from new substation (disconnecting switch transfer)	1.34
3.	Same as 2 except (oil switch transfer)	1.41
4.	13-kv. radial from generating station	1.86
5.	4-kv. network from substation (same as 1)	1.23
6.	4-kv. network from new substation (same as 2) disconnect transfer	1.40
7.	Same as 6 except oil switch transfer	1.44
8.	13-kv. network with 250,000 cir. mil (sec. mains)	1.00

Transformer Vault Design

The single-unit vaults consist of two compartments, usually without a connecting door. The transformer is located in one compartment and the network switch and

Fig. 2—Low-Voltage A-C. Network Vault

other secondary equipment in the other. This design is shown in Fig. 2. Access to each compartment is generally through a separate opening in the sidewalk. Where permits for two openings cannot be obtained, a fireproof door is provided in the dividing wall. This door is hung so as to swing into the closed position when not forcibly held open. The wall between the vault and the basement of the adjacent building is solid without any opening. This design resulted from property damage on customers premises on occasion of vault fires. Openings in the wall between compartments are located 14 in. or more above the floor, and where a door is necessary, a sill 14 in. high or of sufficient height to hold all of the transformer oil within the enclosed space in case of bursted or leaky tanks is built across it. The average floor space required for a single-unit vault

is approximately 64 sq. ft. for a three-phase, and 88 sq. ft. for single-phase primary compartment, 40 sq. ft. for the secondary compartment. The minimum headroom is 10 ft., providing sufficient headroom for future 500-kv-a. transformers. Where more than one bank is used, transformer banks are placed in individual primary compartments of reinforced concrete thus isolating each bank. One installation recently placed in service contained seven banks. There are numerous others in service with 2, 3, and 4 units. Network switches for such installations are placed together in a single secondary compartment. Designs are available for isolation of secondary units should future operating experience indicate that this is desirable.

Ventilation for the primary compartment is normally by natural draft. Forced draft is provided in a few instances. The secondary compartment is not ventilated unless a booster is installed. With natural ventilation the inlet and outlet are placed in the sidewalk near the building line and covered with sidewalk type gratings. Usually an opening of 4 sq. ft. is obtained. An all-metal trap door is provided below each grating, normally held open by a fusible link. In case of fire producing sufficient heat to melt the fuse, the door will be closed by a counterweight and prevent flames from rising through the grating to the street.

Cable work was reduced to a minimum, especially the secondary work. Primary cable runs from the duct entrance in the wall directly to the pothead which is an integral part of the transformer. In secondary runs for subway type construction, it has been common standard practise in the past to use lead covered cables between the transformer and network switch, with a wiped joint at the transformer. Recognizing that it might be difficult to burn off a fault occurring between phases where 1,000,000-cir. mil or larger cable is used, it was decided to reduce this hazard materially by using a varnished-cambric flame-proof cable with the shortest possible run.

Stud type porcelain bushings are used on the transformer secondary. These bushings are water-tight and provide a ready means of terminating the transformer secondary and at the same time preventing leakage of water into the transformer when submerged. The same type bushing is used on the network protector. The transformer and network protector are thus submersible, and are protected against water seepage through the strands of the flame-proof cable.

The flame-proof cable is continued from the outgoing side of the network protector and terminates in a water-tight, fused junction box. At this point lead cables from the street connect to the wiping bushings. The junction box provides a convenient means of connecting the flame-proof cable to the lead covered cables, providing a water-tight terminal. Vault lighting is supplied through a similar but smaller junction box.

Conclusions

A-c. networks are desirable for the following reasons:

(a) Lower cost of serving the district. Network installations have been found to cost from 80 per cent to as low as 50 per cent of the cost of other systems, effecting a saving in yearly fixed charges.

(b) Economies of operation. These economies result from the use of a higher transmission voltage and a reduction of distribution losses. An important item in reducing these losses lies in the possibility of disconnecting feeders with their transformers during light-load periods.

(c) Elimination of operation costs in substations.

(d) Elimination of maintenance costs in substations.

(e) The network is capable of almost indefinite expansion within a given area, or extension beyond to include greater area. Other radial a-c. systems, such as throw-over or pick-up schemes, soon reach a state of development where it is not possible to foresee clearly how the ultimate load can be served satisfactorily. This has been found to be due in part to street congestion, whereas the study of the network system for such a situation showed ample space for ducts, manholes, and vaults for the ultimate load possible to predict, (based upon present experience and method of estimating load).

(f) Reliability of service. Operating experience of several years by other companies has demonstrated that reliability of service and close voltage regulation can be obtained at lower cost with a-c. networks. These experiences have been duplicated on the properties described above, and as further experiences are obtained, it may be confidently expected that standardization of method of design will result in further economies of construction and operation, and permit giving better service at still lower costs.

Appendix

A number of secondary fault tests were made in conjunction with the network development. From these tests the following conclusions were drawn:

Conclusion from Tests. 1. A 500,000-cir. mil cable, in either iron or fiber pipe, can be burned clear with currents of 5000 amperes and above, and 250,000-cir. mil cable with 3500 amperes and above.

2. The resultant explosion, flame, and violence of burning clear a fault on cables larger than 250,000-cir. mils is so severe as to be extremely objectionable from an operating point of view in a congested business district with narrow streets.

3. With a single-conductor cable installed alone in a fiber duct there is no apparent limitation to the size of the copper that can be safely used. The clearing of the fault in this case is not accompanied by explosion or violence but is practically instantaneous due to the rapid fusing of the lead sheath.

4. In general, faults such as conductor to sheath, conductor-to-conductor, established by means of a

pick, drill, etc., are very easily cleared at the point of fault due to contact fusing. In faults where the conductors become solidly connected, the conductor may not be burned clear at this point, but will fuse back often as far as the first manhole, destroying the insulation and lead until physical separation permits it to clear.

5. It was also noted that in a severe type fault there is no difference in the time of clearing a fault with a given amount of current, whether single- or three-conductor cable, and whether it is in an iron or fiber pipe. Faults also were cleared when the manholes were entirely submerged.

6. The resulting flame and explosion can be minimized by the introduction of CO_2 gas in manholes adjacent to the fault.

7. A certain relation between current, time, and conductor size has been established so that it is possible to predetermine with reasonable accuracy what will happen under existing conditions of solid faults.

Abridgment of

A 40,000-Kw. Variable-Ratio Frequency Converter Installation

BY E. S. BUNDY, Associate, A. I. E. E.
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and W. H. RODGERS Associate, A. I. E. E.

***Synopsis.**—This paper describes the installation of two 20,000-kw., adjustable-load, variable-ratio, frequency converters interconnecting the 25-cycle and the 50-cycle systems of the Niagara, Lockport and Ontario Power Company at Lockport Substation about twenty miles from Niagara Falls and Buffalo, N. Y. It also explains the function of the various machines, points out the more important features of the control, and relates a few interesting incidents in the past eighteen months of operation.*

THE Niagara, Lockport and Ontario Power Company was organized in 1906 for transmitting and distributing power in the western and central parts of New York State. The power was generated and transmitted at 25 cycles. Some of the larger customers were distributing companies and municipalities having 60-cycle distribution systems, and in some cases 60-cycle generating equipment. As a result of the difference in frequency between the transmitted power and the distribution systems, several installations of frequency converters were made, each with reserve capacity for emergency use.

In 1927, in order to consolidate the 60-cycle sections of the system and to supply the additional requirement of 60-cycle power to those customers distributing at this frequency, 60-cycle 110-kv. circuits were provided connecting the eastern and western ends of the system. At the same time two 20,000-kw. variable-ratio frequency converters were ordered for installation at Lockport, which is about in the center of both the 25-cycle and 60-cycle systems.

The 25-cycle power system has an installed generating capacity of about 1,000,000 kv-a., of which the Niagara Falls Power Co., the Buffalo General Electric Co., and the Hydro-Electric Power Commission of Ontario system are parts. The 60-cycle power system has an installed generating capacity of about 600,000 kv-a., of which the Niagara, Lockport and Ontario Power Co., the Northern N. Y. Utilities Co., the Mohawk-Hudson Power Corp., and the New England Power Co. systems are parts.

The two 20,000 kw. converters have now been in service for about eighteen months, serving as the main interconnection between the 25- and 60-cycle systems.

The load on these 20,000-kw. sets is inherently adjustable independent of the generating stations and can be maintained constant at any desired load regardless of variations in the frequencies of the two interconnected power systems, provided these variations do not exceed the range for which the set has been designed, *i. e.*, from 98 per cent to 101 per cent of the nominal 25:60 frequency ratio.

Within this frequency ratio range, the converters are completely reversible and can transmit their rating of 20,000 kw. in either direction.

The main synchronous machine and the main induction machine of each frequency converter are capable of operating as a synchronous and an asynchronous condenser, respectively, at a capacity of 20,000 kv-a. zero power factor (over-excited), but not simultaneously. When operating as a condenser, the induction machine is asynchronously excited through its rotor by the regulating machines.

The design of the equipment is somewhat unique and the capacity of each set is between three and four

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Presented at the Great Lakes District Meeting of the A. I. E. E., Chicago, Ill., December 2-4, 1929. Complete copy upon request.

times greater than that of any previously installed frequency converter of similar type.

Fig. 1 is a view showing the two adjustable-load, variable-ratio frequency converters as installed. Fig. 2 is an elevation drawing of one of the main sets showing the physical arrangement of the machines and their foundations. Fig. 3 is a diagram indicating the mechanical and electrical interconnection of the apparatus

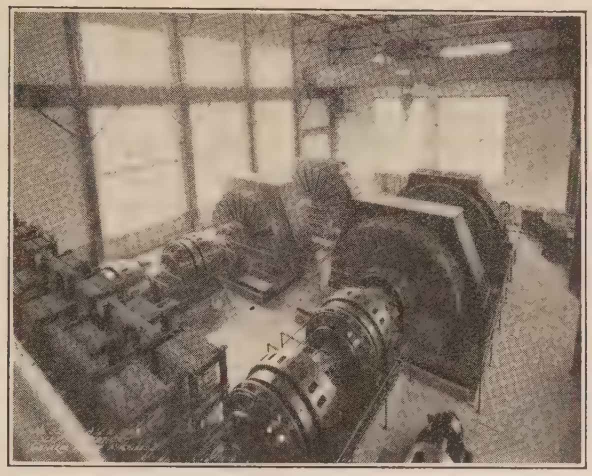


Fig. 1—Two 20,000-Kw. Variable-Ratio Frequency Converters

The two direct connected units in the foreground are those of the double unit regulating machine. The third machine is the main induction machine and in the background is the main synchronous machine. In the left foreground are the accelerating resistors

comprising a set. The captions accompanying the individual figures are explanatory.

Each 20,000-kw. converter consists of a main and an auxiliary set.

Each main set is made up of:

A 25,000-kv-a., (20,000-kw.), 12,000-volt, three-

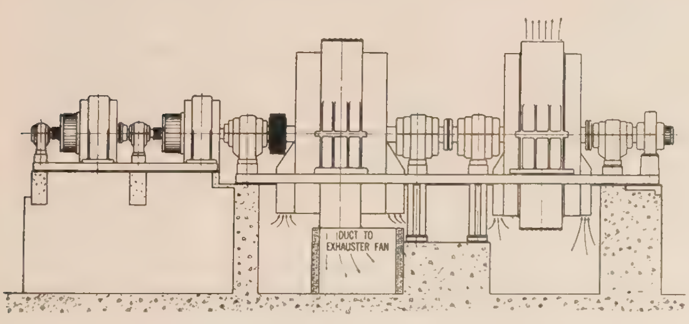


Fig. 2—An Elevation Drawing of a Main Set

To the left are the two units of the regulating machine, then the main induction machine, the main synchronous machine, and to the right the d-c. exciter for the main synchronous machine

phase, 60-cycle, 24-pole, synchronous machine with 165-kw., 250-volt overhung d-c. exciter;

And a 23,000-kv-a. (28,000-hp), 12,000-volt, three-phase, 25-cycle, 10-pole, wound rotor induction machine with a double unit, three-phase, a-c. commutator machine for exciting the rotor circuit of this induction machine. The regulating machine was made in two 375-kv-a., 112.5-volt units connected in series in order to keep the design, particularly that of the commutator, within conservative and reliable limits.

Each auxiliary set is made up of:

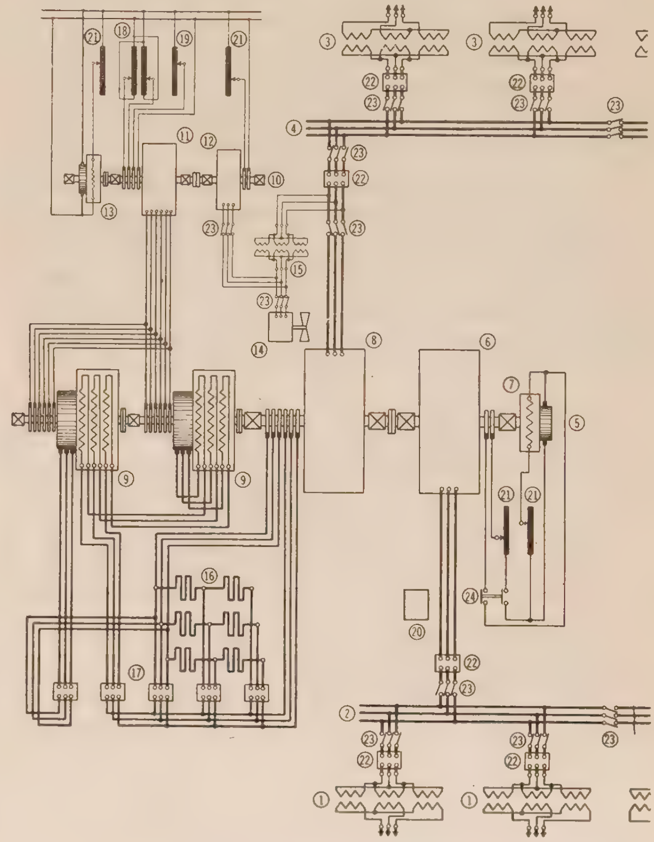


Fig. 3—Connection Diagram of Variable-Ratio Frequency Converter

A fundamental diagram of the set is shown in Fig. 7

1 Transformer: 12,000-kv-a., 110/12-kv.,
2 60-cycle bus. 60 cycle
3 Transformer: 12,000-kv-a., 63.6/12-kv., 25-cycle
4 25 cycle bus
5 Main unit: 300 rev. per min.
6 25,000 kv-a., 60-cycle synchronous machine
7 165-kw., d-c. exciter
8 23,000-kv-a., 25-cycle induction machine
9 375-kv-a., regulating machine unit
10 Auxiliary unit: 750 rev. per min.
11 350-kv-a., 25 cycle synchronous exciter
12 80-hp., 25-cycle synchronous motor
13 17.5-kw., d-c. exciter
14 60-hp., 25-cycle induction motor (exhauster fan)
15 Transformer: 3 × 50-kv-a., 12/0.44-kv., 25-cycle
16 Starting resistors
17 Oil circuit breakers for starting
18 Load rheostat
19 Power factor rheostat
20 Automatic load regulator
21 Field rheostat
22 Oil circuit breaker
23 Disconnect switch
24 Field circuit breaker

A 350-kv-a., 130-volt, three-phase, 25-cycle, four-pole, synchronous exciter for exciting the rotor of the 750-kv-a., a-c. commutator machine;

An 80-hp. 440-volt three-phase 25-cycle four-pole, synchronous driving motor;

And a 17.5-kw., 115-volt, d-c. generator for exciting the fields of the synchronous exciter and driving motor.

Each converter is served by two 12,000-kv-a., three-phase transformers from both the 25- and 60-cycle systems.

The stator winding of the 25,000-kv-a. synchronous machine provides the sole connection of the converter to the nominal 60-cycle power system. Due to the inherent "non-slip" characteristic of synchronous machines, its rotor, and therefore the entire rigidly coupled rotating part of the main set, operate in exact syn--chronism with the actual frequency of the nominal 60 cycle system. In other words, the speed of the main set, which includes the rotor of the main induction machine, is solely determined by the actual frequency of the power system energizing the synchronous machine stator, and is independent of the frequency of the power system energizing the induction machine stator.

The stator winding of the 23,000-kv-a. induction machine is connected to the nominal 25-cycle power system and its stator flux rotates in synchronism with the frequency of this power system. The non-synchronous, "shunt" speed-torque characteristics of an induction machine allows "slip" between its stator flux and rotor speed. Consequently this induction machine is the part of the frequency converter that provides the "loose" coupling between the two power systems so as to accommodate the variations in frequency or departures from the nominal 25:60 frequency ratio.

The double-unit regulating machine and the auxiliary synchronous exciter set constitute the load adjusting equipment for the converter. These machines change the speed-torque characteristics of the wound rotor induction motor.

The regulating machine is the means whereby three-phase alternating voltages at slip frequency and of adjustable magnitude and phase relationship are induced in the rotor circuit of the main induction machine, thereby raising or lowering the "shunt" speed-torque characteristic as desired.

The synchronous exciter of the auxiliary set excites both units of the regulating machine and is the medium controlling the voltages induced by them. This synchronous exciter is essentially a three-phase, 25-cycle synchronous generator except that it has two field windings in quadrature relationship, one controlling the load component of the induced voltage and the other, the power-factor component. In the "load field" is a motor-operated potentiometer type rheostat providing reversible excitation, and in the "power-factor field" is an ordinary motor-operated rheostat. By manipulation of the excitation of this synchronous exciter, load and power factor control of the 23,000-kv-a. induction machine is obtained. These two simple and reliable rheostats are the sole controlling devices.

In starting the converter, the main induction machine is used as a wound-rotor induction motor with secondary accelerating resistors in each of the three separate rotor phases The acceleration is in three steps accomplished automatically under the control of a motor-driven drum type relay. Full speed is reached in less than 90 seconds and the maximum inrush is about 10,000 kv-a.

The converter cannot be started unless the two regulating machine units are disconnected from the rotor circuit of the large induction machine; the second and third accelerating breakers are open; the two rheostats controlling the excitation of the synchronous exciter are in the minimum excitation position; and the motor-driven accelerating relay is in the starting position. All these things being correct, the starting of the converter is initiated by merely turning one control switch. This closes the first accelerating breaker, which is automatically followed by the closing of the main breaker in the primary leads of the main induction machine, and the starting of the motor-driven accelerating relay. The ventilating fan and the auxiliary-exciter set are started at rated voltage simultaneously with the energizing of the induction machine stator. After a period of about 35 seconds, the motor-driven relay closes the second accelerating breaker and 30 seconds later the third accelerating breaker which short-circuits the rotor of the main induction machine. About 20 seconds later, by which time the main set is completely accelerated, the motor-driven relay closes the two breakers connecting the regulating machine units to the rotor circuit of the main induction machine provided the auxiliary exciter set has reached synchronous speed. As soon as both breakers connecting the regulating machine to the rotor of the main induction machine have closed, the three accelerating breakers open, leaving the collector rings of the induction machine connected to the regulating machine units only. This entire sequence is automatically and positively provided and fully insured by interlocking.

After the foregoing has been accomplished, the main synchronous machine may be manually synchronized with the nominal 60-cycle bus and connected to it. Synchronizing is done in the normal way, the speed of the converter being adjusted by manipulation of the load rheostat. This affects the speed for synchronizing just as does manipulation of the governor of a prime mover, and is equally simple. After the converter is connected to both power systems, manipulation of the load rheostat continues to have the same effect as manipulation of the governor of a prime mover driving an alternator, both tending to force or retard the rotor speed and resulting in a change in kilowatt load, the speed being restrained by the synchronous machine.

An automatic load regulator of the rheostat controlling type is provided as a part of the control gear. This regulator governs the load rheostat to maintain any desired transfer of power in either direction, independent of variations in the frequency of either of the connected power systems.

The manually-adjusted power-factor rheostat controls the excitation of the main induction machine, its effect being very similar to the corresponding field and reactive volt-ampere adjustment of a synchronous machine. Normal operation of the induction machine is at 0.95 power factor over-excited.

The control board for the two sets is located in a quiet, well-lighted room about 100 ft. distant from the machine room. The board is of the frameless dead-front stretcher-level-steel type and supports all controlling, protective, and metering devices. The main machines are differentially protected. Overload protection is provided on the supply transformers.

Electrically-operated "latched-in" oil circuit breakers are used throughout. These breakers have demonstrated their reliability fully, there having been not one instance of improper operation since installation.

In case of intentional or automatic opening of the oil circuit breaker in the primary leads of the main induction machine, all devices automatically reset to the proper re-start position except the load and power factor rheostats which must be re-set manually. A re-start can be made within ten seconds after an interruption.

The 80-hp. 750-rev. per min. synchronous motor driving the auxiliary exciter set and the 60-hp., four-pole, squirrel-cage motor driving the exhauster fan are both supplied with 440-volt, three-phase, 25-cycle power through auxiliary step-down transformers, which are connected directly to the stator leads of the main induction machine.

The main set consists of five machines with five rotors rigidly connected together and running at a nominal speed of 300 rev. per min., the actual speed being determined by the actual frequency applied to the stator of the main synchronous machine. This rotating part is supported in six pedestal bearings as indicated in Fig. 2. One structural steel bedplate supports the frames of the main machines and four pedestal bearings; a separate structural bedplate supports the frames of the two regulating units and two pedestal bearings. The operation of the set has been completely successful with this mechanical arrangement.

All machines are self-ventilated except the 23,000-kv-a. induction machine. Because of the small air-gap economically inherent in an induction machine, and the lack of any appreciable fan effect of the smooth drum rotor, the ventilation of this machine is provided by a separate 750-rev. per min. motor-driven exhauster fan having a capacity of 84,000 cu. ft. per minute.

Both ends of each of the three separate rotor phases of the main induction machine are brought out to individual collector rings. The locked rotor secondary voltage per phase is 4080 volts and the current at rated load is 1925 amperes per phase.

The commutation of the series connected a-c. regulating machine units, under all conditions is black. After eighteen months of operation with only normal attention, the commutators are in excellent condition and the brushes are brightly polished over their entire face. The brush life promises to be two or three years at least.

Fig. 4 shows the converter efficiency throughout the load range based on the conditions of greatest loss.

Fig. 5 shows a graphic wattmeter chart of the load on one converter when regulated by means of the automatic load regulator and simultaneous frequency records of the 25-cycle and 60-cycle systems. That part of the wattmeter curve below the center zero line represents a power flow through the converters from the 60-cycle to the 25-cycle system and that part above the zero line represents a conversion of power from the 25-cycle to the 60-cycle system.

The scale of the wattmeter is 25,000 kw. each side of

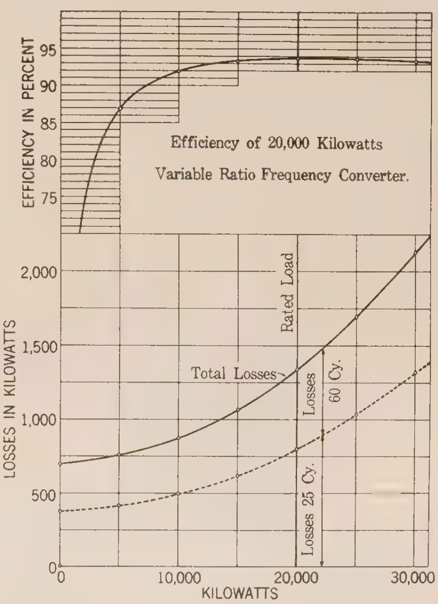


Fig. 4—Performance of the 20,000-Kw. Converters under Maximum Loss Conditions

the zero center line and it will be noticed that at 3:30 p. m. the load reversed through the converter, changing from 17,000 kw. in one direction to 17,000 kw. in the opposite direction. This resulted from the loss of generating capacity on the 60-cycle system, which made it necessary to supply the deficiency from the 25-cycle system. Coincident with this power disturbance, the frequency of the nominal 60-cycle system decreased materially (to 58.7 cycles) the nominal 25-cycle system evidenced no very appreciable reaction due to the relatively small change in power on this system, particularly from considerations of the 25-cycle system inertia.

Since installation, both units have been in practically continuous operation. In the flood season, the surplus power from the 60-cycle system is supplied to the 25-cycle system through the converters. During the low water season, part of the 60-cycle system load is carried from the 25-cycle system through the converters.

During the first 12 months operation 80 per cent of the power through the converters was converted from 60 cycles to 25 cycles and 20 per cent was in the opposite direction.

The complete paper describes and explains the characteristics of such a converter more fully and, more intimately, the operation and design of the component apparatus, using rather generally known and understood analogies, comparisons, and simple physical conceptions without any mathematical analyses or difficult theoretical treatment.

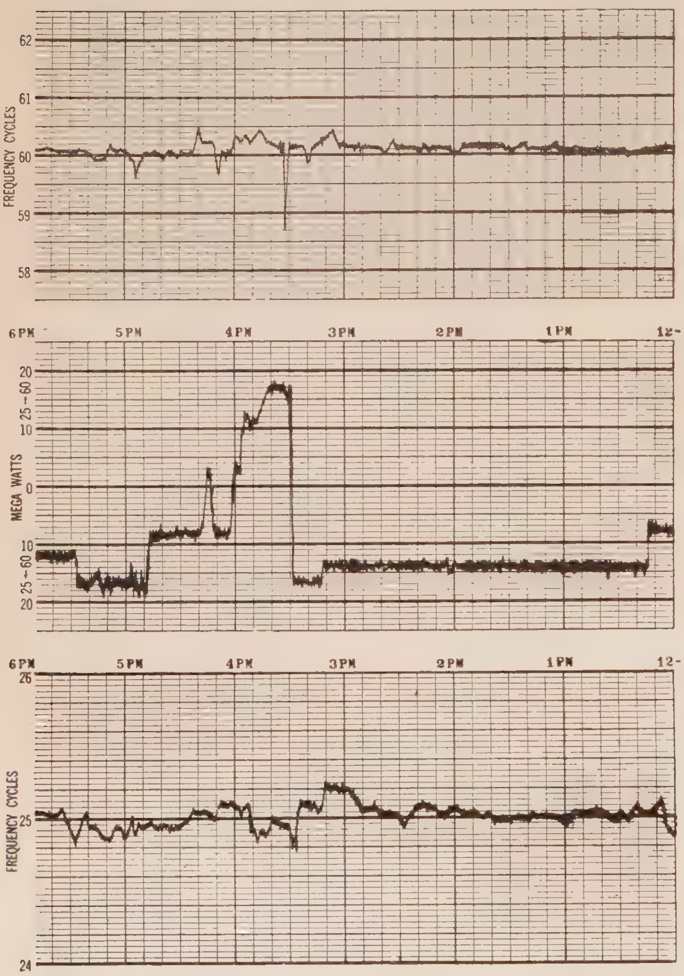


Fig. 5—Simultaneous Load Transfer and 25-Cycle and 60-Cycle Frequency Records

The top chart shows frequency of the 60-cycle bus; the middle chart shows megawatts, and the bottom chart shows frequency on the 25-cycle bus

Variable ratio frequency converters will be fittingly selected for application where the operating economy or convenience of load adjustment at the converter justifies their somewhat higher cost and slightly lower efficiency. There will be other instances where necessity dictates the use of such converters in order to provide a sufficiently reliable connection between systems. It is impossible to specify generally the system conditions requiring variable ratio converters. In determining the proper type and size of any form of interconnecting equipment not only the capacity of the systems but also the general and specific capacity of the other metallic and electromagnetic connections within a system should be considered. Recent experience with automatic frequency regulators reveals the fact that normal frequency fluctuations can be controlled within very close limits by load regulation of a surprisingly small percentage of system capacity. From this fact it is apparent that the normal tendencies of two interconnected systems to depart from a constant frequency ratio can be counteracted by at least a correspondingly small transfer of load from one system to the other. Actual operating experience has shown that two power systems may be connected together successfully by synchronous-synchronous frequency converters having a capacity of only ten per cent of the capacity of the smaller system. Where the capacity of the desired interconnecting apparatus is less than ten per cent some uncertainty exists regarding the suitability of the more rigid types of converters and the application of variable ratio converters should be carefully considered.

LIGHT IN ARCHITECTURE AND DECORATION

The *Transactions* of the Illuminating Engineering Society, introduces a new department in the current issue devoted exclusively to Light in Architecture and Decoration. Succeeding issues will contain editorials concerned with various phases of modern lighting as related to architecture and decoration, together with a series of illustrations representing installations of unusual interest with descriptions of their essential features.

There is no doubt that we are entering a new period in lighting, reports the Committee on Light in Architecture and Decoration. With this new movement we are seeing the lighting planned as a component part of and coincident with the structure itself. In general, the luminaires are designed to carry out in line and decoration the spirit expressed in the architecture. Department stores and exclusive shops have been quick to see the advantages of unique lighting in creating a distinctive atmosphere designed to attract the potential customer, and large office buildings, hotels, and clubs are giving more attention to lighting than ever before.

New styles of architecture are not essential for the application of modern lighting. This is illustrated in one of the examples shown in the current issue of the *Transactions* where an interior in Mayan decoration has been lighted in a twentieth century manner which thoroughly emphasizes the decorative scheme.

There is a tendency on the part of the uninformed to think of lighting as "art moderne" if it is made up of panes of frosted glass arranged in rather bizarre geometric designs. This is just one phase of the whole movement, however, and will be either radically improved or will pass out of the picture.

Abridgment of

Three Regions of Dielectric Breakdown

BY P. H. MOON[1] and A. S. NORCROSS[1]
Member, A. I. E. E. Associate, A. I. E. E.

Synopsis.—*In a previous paper, the writers published results on the dielectric strength of various glasses and concluded that for ordinary thicknesses there were three distinct types of breakdown. The present paper emphasizes the fact that this is true not only for glass but also for fused quartz and for celluloid. By the elimination of edge-effect, the following breakdown gradients were obtained: For celluloid, 2,500,000 volts/cm.; for glass, 3,100,000 to 5,000,000 volts/cm.; and for mica, 10,600,000 volts/cm. The various methods of eliminating edge-effect are discussed and compared and an attempt is made to correlate the electrical properties of the glasses with their chemical composition.*

* * * * *

ONE of the most outstanding advances in dielectric testing methods made in recent years has been the elimination of edge breakdown. In the past, uniform materials, such as glass and mica, failed almost invariably at or near the electrode edge, and it is only within the last few years that this trouble has been eliminated.

Thanks principally to the excellent work of Inge and Walther of Leningrad,[2] there are today several methods of forcing the punctures to occur in the uniform field under the electrode. Inge and Walther eliminated "edge-effect" by testing thin spheres blown from glass tubing. They also made use of special semi-conducting baths in testing flat specimens. By these methods they were able to increase the breakdown gradient to about ten times the usual value, and thus apparently obtained the true breakdown strength of the material. Their curves showed the region of thermal breakdown as well as the "disruptive" breakdown region, but failed to give conclusive evidence as to what lay between the two.

Accordingly, an investigation was begun at M. I. T. to study the matter in greater detail. Numerous breakdown tests made on hollow glass spheres during the summer of 1928 led the writers to the belief that for ordinary thicknesses, there existed *three distinct types of breakdown* rather than two. The results of these tests were presented by Doctor V. Bush before the Insulation Committee of the National Research Council in November 1928. They have also been published.[3]

Further work by the writers and by six other investigators, using different apparatus and various methods, has led to the same conclusions. The investigation has been extended to various glasses, fused quartz, celluloid, and mica. The purpose of this paper is to present a résumé of all the breakdown data recently obtained in the Electrical Research Laboratories of the Massachusetts Institute of Technology.

Apparatus and Methods

All tests were made with direct potentials obtained either from a 100-kv. kenotron set or from a 4000-volt motor-generator set. Voltages were measured with a 100-kv. electrostatic voltmeter or with a D'Arsonval voltmeter equipped with a 20-kv. multiplier. Most of the tests on spheres were made with the apparatus previously described,[4] while tests on flat specimens were made in various semi-conducting baths or in air within an electric oven specially designed to maintain a constant temperature throughout the interior. Two sets of electrodes were used, one with sharp edges and one with edges rounded to a 3.2-mm. radius. Both had the same area in contact with the dielectric, this area being 15.9 mm. in diameter. Freezing mixtures and solid CO^2 were used in obtaining low temperatures. Thickness was measured with a micrometer by taking the lowest of half a dozen readings made in the immediate vicinity of the puncture.

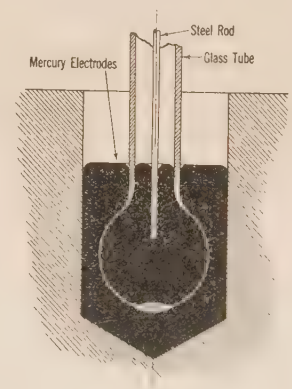


Fig. 1—Form of Glass Specimen Used in Breakdown Tests

The Three Regions—Tests on Spheres

G-1 Glass. The results obtained on G-1 glass spheres are shown in Figs. 2A and 2B. Here the potential differences are expressed in kilovolts and the thicknesses

1. Both of the Massachusetts Institute of Technology, Cambridge, Mass.

2. Inge and Walther, "Durchschlag von Glas in homogenen und nichthomogenen elektrischen Feldern," *Archiv. f. El.*, 19, 1928, p. 257, *Archiv. f. El.*, 22, 1929, p. 410.

3. Moon and Norcross, "Three Mechanisms of Breakdown Obtained on Glass by Elimination of Edge-Effect," *Franklin Inst. Jl.*, Dec. 1929.

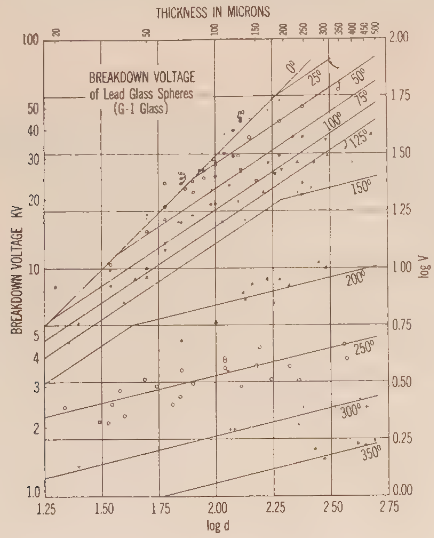
Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

4. Moon and Norcross, *loc. cit.*

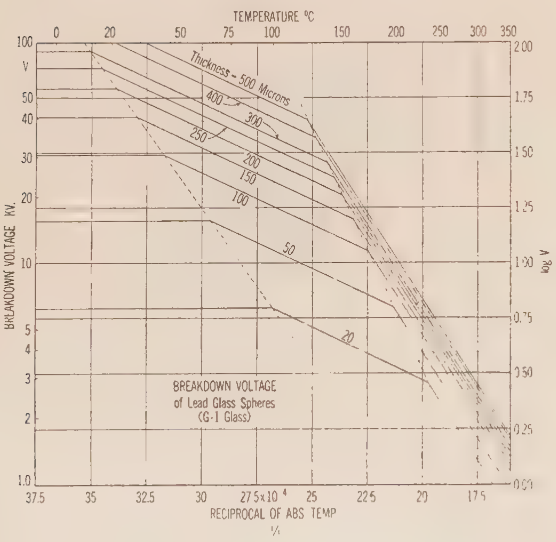
in microns ($1\ \mu = 0.001$ mm.). In Fig. 2A the logarithm of breakdown voltage is plotted against the logarithm of thickness in order to obtain straight lines. Each point represents a single breakdown measurement. It will be noted that the results seem to fall into three classes:

1. At low temperature, the breakdown curve has the slope of unity. ($V = K_1 d$)

2. At higher temperatures, the points are well represented by a straight line with the slope 2/3



A



B

Figs. 2A, 2B—Breakdown of Lead Glass (G-1 glass) Spheres

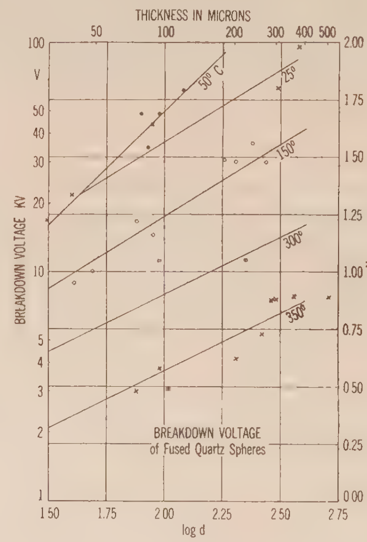
($V = K_2 d^{2/3}$). This is shown by the 125-deg. points.

3. At the temperatures of 200 deg. and above the slope is less ($V = K_3 d^{0.25}$), which is clearly exemplified by the 250- and 300- deg. data.

The same curves are replotted against the reciprocal of the absolute temperature in Fig. 2B. This shows the three regions of breakdown mentioned above. At low temperatures the breakdown voltage is independent of temperature. This is usually called the "disruptive" region.

At very high temperatures the breakdown voltage varies rapidly with the temperature according to an exponential relationship. This has been shown[5] to be thermal breakdown.

At temperatures between the other two, the voltage also appears to vary exponentially as the reciprocal of the absolute temperature, though the variation is less rapid than in the thermal region. For want of a better name, we have termed this the "intermediate region."



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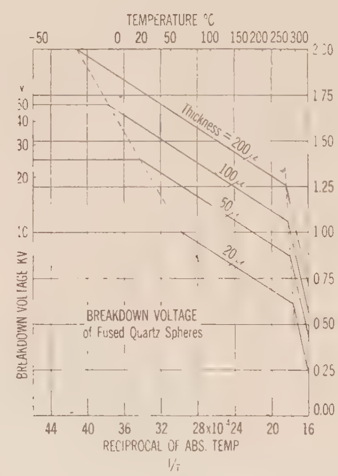

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4A, 4B—Breakdown of Fused Quartz Spheres

Fused Quartz. Fig. 4 gives the results obtained to date on fused quartz spheres. The samples were blown from clear transparent Vitreosil tubes by use of the oxy-hydrogen flame and were similar in size and appearance to the ones blown from glass tubing. The work on fused quartz is not yet completed, which accounts for the small number of points. However, the data seem to uphold the previous work.

The Three Regions—Flat Specimens

Cover Glass. The first tests on flat samples were made on German microscope cover glass 4 cm. square and about 200 μ thick immersed in a semi-conducting

5. Moon and Norcross, *loc. cit.*

bath. The specimens were beautifully flat and uniform and gave very consistent results as shown in Fig. 5. Each point represents one breakdown. The intermediate region here appears as the long, straight portion from room temperature to about 170 deg. The thermal region also is evident. No doubt the disruptive region will too be found when tests are made at lower temperatures.

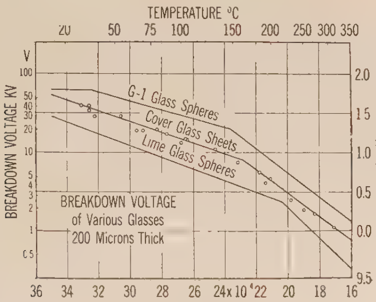

FIG. 5—BREAKDOWN OF VARIOUS GLASSES (200 MICRONS THICKNESS)

Curves for G-1 glass spheres and line glass spheres of the same thickness are also included in Fig. 5 for comparison. Except for slight differences in the slopes, the curves are very similar.

Celluloid. The results obtained on 125 μ celluloid are shown in Fig. 6. This curve proves that the three regions of breakdown are not confined to glass but may appear with other materials. It is also interesting to note that the breakdown gradient in the disruptive region is 2500 kv./cm. This is not so high as that for glass, but is much higher than is usually found for celluloid. This high gradient is, of course, the result of eliminating breakdown at the electrode edge.

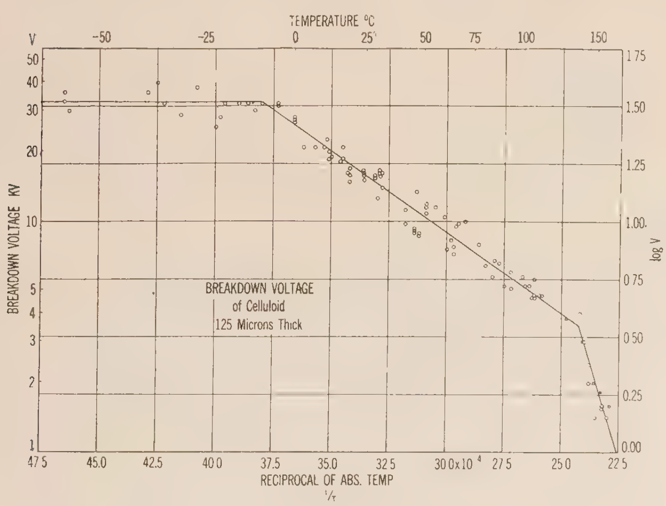

FIG. 6—BREAKDOWN OF CELLULOID (125 MICRONS THICKNESS)

The few points shown by squares were obtained in air and are seen to check the other tests which were made in semi-conducting baths. However, samples tested in air at temperatures below 140 deg. cent. (the critical temperature for celluloid of this thickness) invariably broke at the electrode edge. This criterion was used to determine the sharp break between the thermal and intermediate regions, and the critical temperature thus obtained checked that from the intersection of the two curves. This is a well-known property of the thermal region: edge-effect does not enter and no semi-conducting bath is necessary. In the other two regions, however, some effective method of eliminating edge breakdown is absolutely required.

Mica. An investigation was made of the breakdown of India mica at room temperature. Both sharp-edge and rounded-edge brass electrodes were used and were found to give the same results. Fig. 7 shows the final data obtained by using a bath of xylene + 20 per cent aniline and sharp-edge electrodes. It will be noted that there is a linear relationship between voltage and thickness, the average breakdown gradient being 10,600 kv./cm. This linear relationship indicates that these breakdowns are in the disruptive region. Besides the circles (room temperature) of Fig. 7, a few crosses will be noted. These represent breakdowns at 100 deg. cent. using the same electrodes and same bath. Evidently the breakdown strength has not been reduced by the increase in temperature, which supports the idea that the mica is operating in the disruptive region.

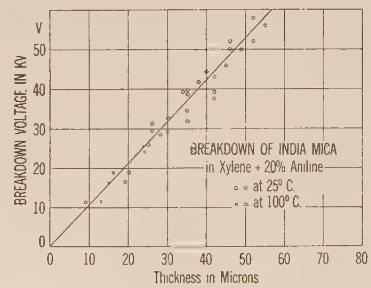

FIG. 7—BREAKDOWN OF INDIA RUBY MICA (IN SEMI-CONDUCTING BATH OF XYLENE + 20 PER CENT ANILINE)

0 = 25 deg. cent.
x = 100 deg. cent.

SUMMARY OF RESULTS

The data indicate that the breakdown voltage of various glasses, celluloid, and fused quartz on direct potential can be expressed by the equation:

$$V = K_i d^{n_i} (10)^{b_i/T}$$

where

V = breakdown voltage in kilovolts
d = thickness in microns
T = absolute temperature
K, n, and b are constants determined by experiment
i denotes the region considered: $i = 1$ for disruptive, $i = 2$ for intermediate, $i = 3$ for thermal.

The values of n and b for the three regions are tabulated below:

TABLE V

Material	Effect of Thickness				Effect of Temperature		
	K_1	n_1	n_2	n_3	b_1	b_2	b_3
Fused quartz (non-pol. elec.)	5,000	1.00	.63	.50	0	330	2250
Pyrex	4,800	1.00	0.70	..	0	715	..
Cover glass	..	..	..	..	..	687	1500
G-1 glass	3,100	1.00	0.66	0.25	0	470	1540
Lime glass	..	1.00	0.63	0.185	0	735	1910
Lime glass (non-pol. electrodes)		1.00	0.63	0.45	0	735	1530
Celluloid	2,500	1.00	..	..	0	705	3300
Mica	10,600	1.00	..	..	0	..	..

It will be noted that in the intermediate region n_2 varies between 0.63 and 0.70 for the different materials, and it seems probable that a value of $2/3$ is very nearly correct for all these dielectrics. Thus it may be stated that in the intermediate region the breakdown voltage varies as the $2/3$ power of the thickness. The values of n_3 vary through a wider range, but this is explicable on the basis of the Fock thermal theory[6] which allows any value from 0 to 0.50. The values of b_2 and b_3 do not differ greatly in the various materials and the values of b_3 check the Fock theory satisfactorily.[7]

Table VI attempts to correlate the resistivity and breakdown voltage of the various glasses with the chemical composition.

TABLE VI
CHEMICAL COMPOSITION AND BREAKDOWN STRENGTH

Material	% SiO_2	% Na_2O + % K_2O + % CaO	log ρ_{25}	Kilovolts per cm. Disruptive	Kilovolts per cm. Intermediate[1]	Kilovolts per cm. Thermal[2]	Deg. cent. θ_{c1}	Deg. cent. θ_{c2}
Fused quartz	99.8	trace	19.0[4]	5,000	1815	560[3]	−31	270[3]
Pyrex	80.8	4.5	13.8	4,800	1050	200	−20	140
G-1 glass	66	13.8	14.9	3,100	1200	102	+22	150
Cover glass			12.7	....	730	60	+20	165
Lime glass	69.7	21.0	11.5	4,500	355	32	−33	217
Celluloid (125 μ)				2,500	420	....	−10	140
India mica			16.3	10,600			+100	..

NOTE. ρ_{25} is the resistivity at room temperature (value of A at 25 deg. cent., approximately).
1. For 200 μ and 100 deg. cent.
2. For 200 μ and 300 deg. cent.
3. With non-polarizing electrodes. Ordinary electrodes would probably give a higher breakdown gradient in the thermal region and a greater θ_{c2}.
4. Obtained from R. B. Sosman, "Silica," Chem. Catalog Co., 1927, p. 528.

The critical temperatures θ_{c1} and θ_{c2} have also been tabulated. These are the temperatures at which transition occurs from one type of breakdown to the next.

CONCLUSIONS

The elimination of edge breakdown greatly increases the puncture voltage of solid dielectrics. Within the limits of experimental error, the same results are obtained with the different methods of edge-effect elimination: hollow spheres, also flat sheets in semi-conducting baths. Repeated checks with various semi-conducting baths show that all baths give the same breakdown voltage provided the resistivity is adjusted to prevent failure at the electrode edge.

In the disruptive region the breakdown gradient is independent of both temperature and thickness.

In the intermediate region the breakdown voltage varies approximately as the $2/3$ power of the thickness and exponentially as the reciprocal of the absolute temperature.

In the thermal region the voltage varies as the $1/2$ or lesser power of the thickness and as an exponential function of the reciprocal of the absolute temperature.

The rate of voltage rise has no effect on the breakdown voltage in the disruptive and intermediate regions. This statement applies only to the range of voltage rise from about 1000 volts/sec. to 20 volts/sec. and is not to be construed as applying to transients. In the thermal region, the rate of voltage rise has a very marked effect for rates which give breakdowns in less than five or ten minutes.

No effect of electrode area could be detected with glass spheres having a range of areas of about 10:1. This conclusion, of course, applies only to homogeneous materials.

Electrode material has no apparent effect on breakdown voltage in the disruptive and intermediate regions. In the thermal region, however, it may have considerable effect.

Electrolytic polarization does not appreciably alter the disruptive and intermediate breakdown voltages. However, non-polarizing electrodes greatly increase the conductivity of glass and thus decrease the puncture voltage in the thermal region.

There appears to be a direct correlation between the SiO_2 content of a glass and the disruptive breakdown strength. In the thermal region a similar correlation can be found between total alkali content and breakdown gradient.

In conclusion the authors wish to express their thanks to those whose help has made this paper possible. To Dr. V. Bush, under whose direction the research was conducted, the authors owe much. Thanks are also due to Mr. M. O. Porter, Jr. for permission to use the data which he obtained on the breakdown of celluloid (Fig. 6) and to Mr. L. A. Bingham for most of the work on

6. V. Fock, "Zur Wärmetheorie des elektrischen Durchschlages," *Archiv. f. El.*, 19, 1927, p. 71.
7. Moon and Norcross, *loc. cit.*

fused quartz (Fig. 4). Messrs. R. A. Swan and W. F. Bartlett are responsible for the data on Pyrex, while Messrs. W. E. Creedon and W. E. Lowery obtained the results on line glass at − 60 deg. cent. We also wish to thank the Corning Glass Works which made the flat sheets of G-1 glass especially for this investigation, and the Thermal Syndicate, Ltd. who furnished the Vitreosil tubing.

Abridgment of

Experience With Carrier-Current Communication on a High Tension Interconnected Transmission System

BY PHILIP SPORN[1]
Member, A. I. E. E.

and

RAY H. WOLFORD[1]
Non-member

Synopsis.—*The paper outlines the fundamentals of a carrier communication system over a transmission network.*

A description of the installations on a 132-kv. network having an extent of 2500 linear miles is given and the general experience with carrier, which is the sole means of communication used by the power companies on that system, is outlined.

Extensive experience with various types and makes of coupling capacitors is described. Experience with the protective system, the lead-in system, the tuning used in connection with the coupling, the transmitting system, and the receiving system is given. Definite data are cited as to cost, maintenance, reliability, traffic, and safety.

* * * * *

INTRODUCTION

A number of papers on carrier-current has been given before the Institute on various phases of carrier-current communication. Most of these papers have been presented by manufacturers' engineers. In the two cases where operating engineers have presented papers they covered operation of a carrier-current installation on either a single or on two lines, the maximum number of terminals considered being three.

To date no paper has been presented either by a manufacturing or an operating group that gave operating experience with carrier-current telephony on a transmission system or described a complete system of carrier-current communication.

It is quite patent that two or three sets do not make up a system and that the practicability of any system of carrier-current communication cannot be determined from the operating results obtained with two or three sets. Besides, the isolated line utilized for transmitting a block of power from a generating point to a point of use is decidedly the minority case today, and is more likely to be so in the future. We are rapidly approaching the point where the country will be covered by a network of interconnected transmission lines.

The American Gas and Electric Company's subsidiaries have been associated with carrier-current operation from its very inception and are operating a larger single transmission high-voltage network than operated by any other group. The experience obtained on this network primarily and on other portions of the system in the operation and application of carrier may, therefore, be expected to be of interest to other members of the Institute.

FUNDAMENTALS OF A CARRIER COMMUNICATION SYSTEM OVER A NETWORK

Based on our experience with an interconnected

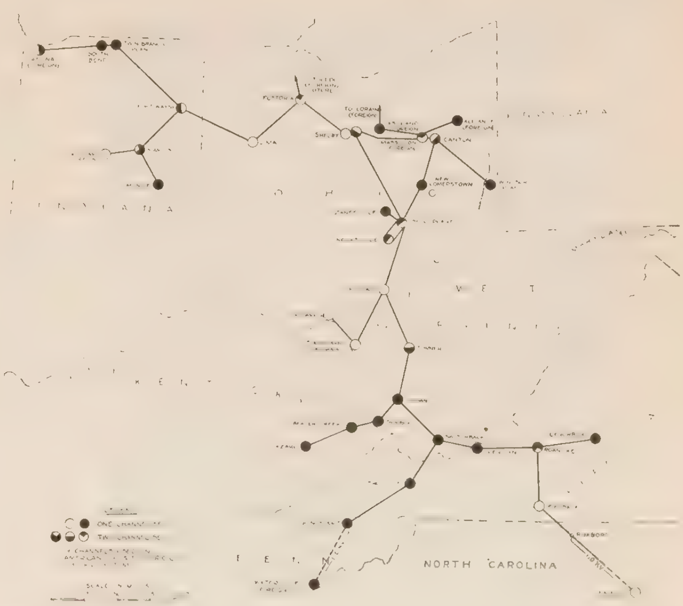

FIG. 1—DIAGRAM SHOWING CARRIER CHANNELS ON AMERICAN GAS AND ELECTRIC CO. 132-KV. SYSTEM

system, the more important communication requirements include the following:

1. Ability of any one station on a channel to cut in on a conversation if it has anything of an emergency nature to report. It is to be noted that this is a definite

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1. Both of the American Gas and Electric Company, New York, N. Y.

Presented at the Great Lakes District Meeting of the A. I. E. E., Chicago, Ill., Dec. 2-4, 1929. Complete copy upon request.

reversal of what is considered a prerequisite in ordinary telephone conversation.

2. Reliability.

3. Ability to furnish a maximum number of channels on any one system.

Description and General Experience

Fig. 1 shows the 132-kv. system under consideration and indicates the channel arrangement now in operation.

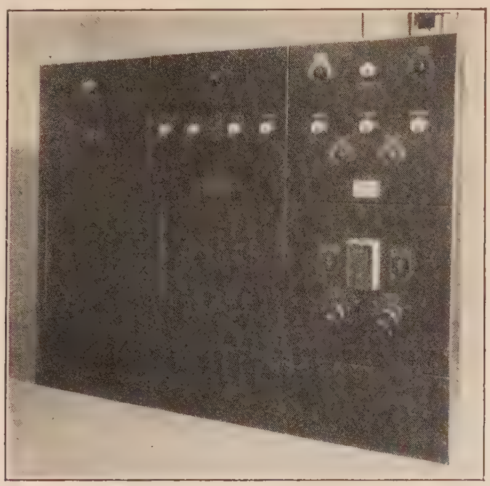

Fig. 2—General Electric Co. 50-Watt Primary Set, Type CC-8B, Ohio Power Co., Fostoria, Ohio

All these sets are single-frequency, duplex, selective ringing, of General Electric Company manufacture.

Fig. 2 shows one of the latest type CC-8B, 50-watt sets installed within the last two years. On the portion of the network shown, 10 channels are utilized.

The general experience with this carrier system has been highly satisfactory from the very beginning. There were troubles in the early days, particularly with the simplex ground return sets, in signaling, in getting through, and in the quality of speech; difficulty was experienced as the number of sets increased in maintaining proper separation between the various channels; trouble was experienced with some of the types of coupling capacitors employed; but on the whole, carrier has for the past five years provided on this system the principal means of load dispatching and of maintaining contact on all similar and related business without any outside supplement. Again and again when all other sources of communication in a particular district failed, carrier continued to provide service of the same high type and of the same high quality as it provided under normal conditions.

The development of carrier on our system has demonstrated the fact that carrier on our system has reached a stage where it will, if properly applied, provide a quality of communication with a reliability that is generally obtainable at present through no other source at the same cost.

On the southern portion of the A. G. & E. Co. system there were installed at one time 12 Western Electric sets. Here the operation of the sets was continued for a period of approximately three years, at the end of which time the sets were all removed and put in service on isolated networks operating at lower voltages.

The main difficulty experienced with these sets was that fundamental one brought about by the two-frequency system, which did not permit more than two stations to enter into the conversation at the same time.

Fig. 3 shows the 66-kv. transmission system of the Atlantic City Electric Company. Carrier has provided the principal and practically only communication on the entire system and has done it with a reliability unequalled by any other communication that had been obtained on the system until the introduction of carrier. In 1927, during a particularly severe storm along that entire section of the Atlantic coast where all other forms, including all commercial forms of communication in the territory, were very seriously crippled, communication between Atlantic City and the then extreme point, Woodstown, was maintained by carrier without the slightest interruption.

Coupling System Experience

Antenna coupling, at first one-wire and later two-wire, was originally utilized with fair success. However, it was found to be subject to variations from time to time; installation difficulties were encountered because the towers were not designed for the antenna conductors and because most double-circuit transmission lines are now strung asymmetrically; consequently, capacitor coupling was adopted throughout the system. Mica dielectric capacitors (Fig. 4) being the only type available, were first used. Other types of capacitors were later developed and after extensive tests the cable type capacitors (Fig. 5) was principally used for the 132-kv. system, and the mica type capacitors are gradually being relocated on lower voltage systems

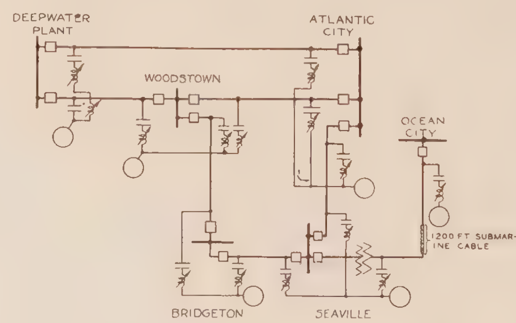

Fig. 3—Schematic Diagram Showing Coupling and By-Passing on Atlantic City Electric Co. System

where they are performing satisfactorily. A later modification of the cable type capacitor as shown schematically in (Fig. 6) consists in combining with it a current transformer. Experience with the cable type capacitors, whether of the straight type or combination type, has been uniformly successful and covers now a period of three years, in which time there has not been a single breakdown, although approximately 80 of these units are installed on the 132-kv. system at the present time. Various minor troubles experienced have now been eliminated.

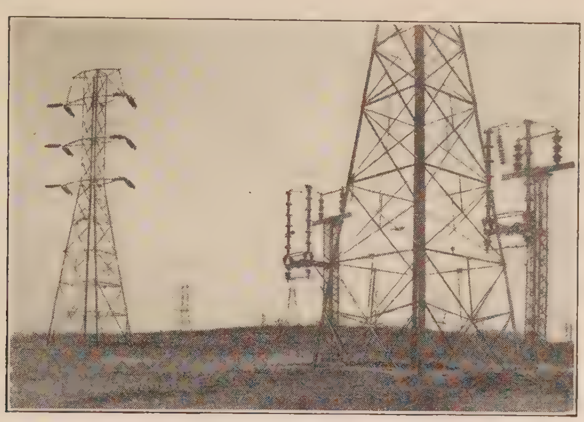

Fig. 4—Mica Dielectric Capacitor Installation, Ohio Power Co., Canton, Ohio

Believing operating experience with other types of coupling equipment desirable, in case some unexpected operating experience developed with the cable type capacitors, several installations of the oil dielectric tank type capacitors were made. Fig. 7 shows an installation of this type, at Philo, Ohio. No trouble has been experienced with the tank type of capacitor.

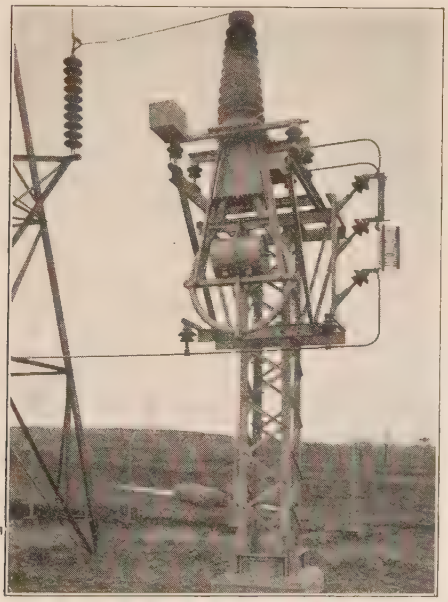

Fig. 5—General Electric Co. Cable Type Capacitor Installation, Ohio Power Co., Canton, Ohio

Two combination oil and porcelain 132-kv. capacitors of 0.007 μ f. total capacity were tried out but four separate failures on the two capacitors led to their abandonment. They were replaced by porcelain multi-unit type capacitors (Fig. 8). Operating experience on the porcelain multi-unit type covering a period of one year has been entirely satisfactory. Six months operating experience on a 66-kv. installation of this same type has also been entirely satisfactory.

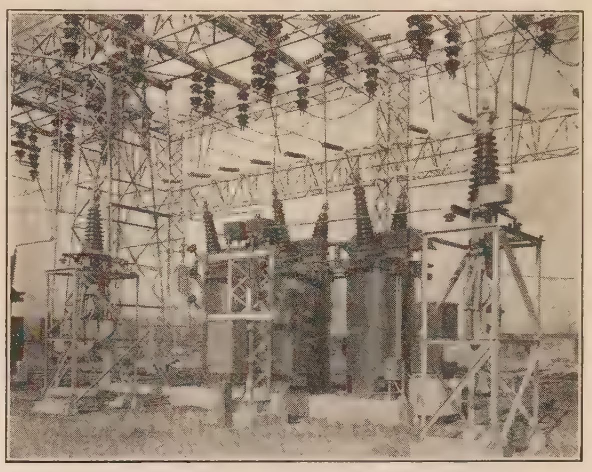

Fig. 6—General Electric Co. Combined 132-Kv. Cable Capacitors and Current Transformers, Indiana General Service Co., Marion, Ind.

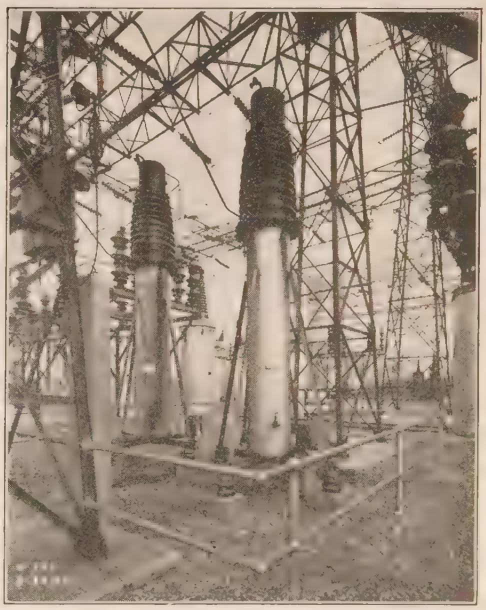

Fig. 7—General Electric Co. 132-Kv. Tank Type Capacitors, Ohio Power Co., Philo, Ohio

In view of all the above it is believed that the coupling problem has been solved very definitely and that equip-

ment is available today with as high a factor of safety, if not higher, as is obtained in all the other links of the transmission chain. Some progress can still be made in the direction of reducing costs, and it is believed this will come about in the future.

Experience on Other Apparatus

The extensive protective system originally used with coupling capacitors has been gradually simplified. This protective system has in no case failed to function as contemplated or to take care of any situation that has arisen on the power end during the entire period covered.

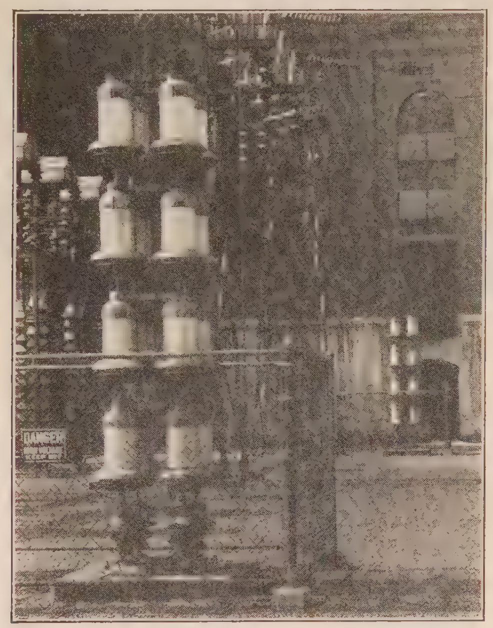

Fig. 8—Ohio Brass Co. 132-Kv. Dry Type Porcelain Capacitor Assemblies, Appalachian Electric Power Co., Cabin Creek, W. Va.

Originally all lead-in conductors had to be overhead construction. This resulted in costly construction, additional hazards, and unsightly appearance, and sometimes interfered with future construction. As a result of considerable development on this problem, practically all lead-ins have now been placed underground. At first the maximum length permitted was 600 feet. The recent laboratory development and test of a special impedance matching transformer indicates that underground lead-ins can be used up to any length required in a commercial installation.

Equipment for tuning and bypassing has been developed to a high state of efficiency and flexibility. Fig. 9 shows schematically the carrier telephone installations on the systems of the Pennsylvania Power & Light Company and The Scranton Electric Company. Communication between Harwood and Wallenpaupack is provided either by way of Sigfried or by way of Stanton and Scranton. Bypass equipment is utilized around voltage transformations and around the inter bus reactor at Stanton. Various irrelevant lines and apparatus are trapped out to prevent excessive loss.

The transmitter is quite simple and practically no trouble has been experienced with it.

In the earlier types of equipment the receiver tuning system consisted of two simple coupled tuned circuits feeding a non-regenerative detector. As the number of stations on the system and the number of channels increased, it was found that this simple tuning system was not sufficiently selective. This brought about the development of receiving systems having higher selectivity characteristics. A high degree of selectivity is now secured by four coupled tuned circuits, the last one of which feeds into a four-element screen grid tube used as a radio frequency amplifier. This radio frequency amplifier feeds into a non-regenerative detector.

Of all of the component parts of the carrier communication system, the signaling system has probably given more trouble than any of the others. In the later models the signaling system has been very greatly improved, and within the last two years very little trouble has been experienced.

Realizing the extreme importance of the signaling system, all stations have been provided with supplementary loud speaker calling. This has been found to be of great value, particularly during times when the transmission system is in distress, as the loudspeakers at all stations can be connected and instantaneous voice calling used.

In the earlier sets the power supply equipment, although fundamentally practical, caused trouble for various reasons. In later sets the power supply equipment has been completely redesigned for communication service. This later equipment has proved practical and reliable, and it requires in general only routine maintenance.

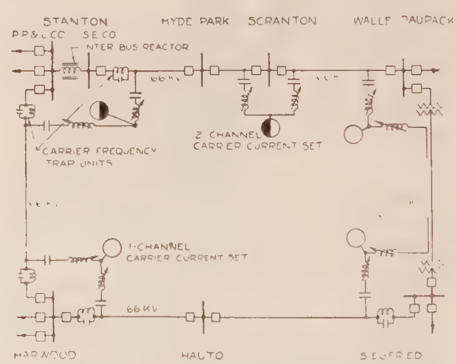

Fig. 9—Schematic Diagram of Coupling, Tuning, and By-Passing on Interconnected Systems of Scranton Electric Co. and Pennsylvania Power and Light Co.

The carrier telephone system is being used primarily

for dispatching and very little other communication is allowed to go over it. For this reason, very few extensions to the carrier equipment have been required. One such extension is in operation at Canton, Ohio, between the substation and the main office, about two miles distant. This extension is made over a pair of telephone wires in a cable circuit leased from the telephone company. The extension has operated entirely satisfactorily.

Cost of Installations

The cost of installations will vary not only with the type of sets employed but with the number and the voltage of the coupling points at a particular station and whether or not more than one frequency channel is employed at that station. Up to the present time line coupling exclusively has been employed on our 132-kv. system. It is possible, of course, to reduce this cost considerably by going to bus coupling. However, on the basis of the coupling practise followed, the average cost per terminal has been running in the neighborhood of $15,000. This includes all the overheads. The cost of the 30 terminals therefore represents an investment of approximately $450,000.

These 30 points provide communication for a total of 1340 linear miles of 132-kv. line. It is estimated that the cost of a single leased line to provide approximately equivalent communication would amount in rentals to approximately $72,500 per annum.

Complete data on maintenance are not available over the system as a whole, but on one portion of the system, where cost records were kept, the maintenance cost of 18 sets in 1928, including all the necessary personnel, was approximately $9000 or $500 per year per set. Utilizing this unit figure, the maintenance for the 132-kv. system represents a total of $15,000 per annum. Allowing 15 per cent for fixed charges, the total cost of the carrier communication system is $82,500 per year, the difference between the two forms thus being a total of $10,000 per year. Against this additional expense there is the following to be balanced.

1. Quality. The quality obtained over the carrier system has in general been equal to and in many cases better than what would pass for good commercial telephone quality. It is generally equal to the quality obtained in an all-cable commercial system, and in the territory covered, it is practically impossible to obtain an all-cable line of any appreciable length.

2. Reliability. The reliability of the carrier communication system has undoubtedly been superior to that of any other form of communication obtainable in the territory.

Maintenance, Reliability, Traffic, and Safety

In general, maintenance has been confined to routine inspection. Many matters that have given considerable trouble during a portion of the time covered have, through attention to that particular phase, been brought up to the point where they have been completely eliminated as a main source of trouble. Today, therefore, with the elimination of coupling, calling system, and similar troubles, only routine maintenance is necessary. It is believed that as time goes on, the maintenance cost can be cut from 20 to 30 per cent.

The experience on our system has been that in many cases when contingencies develop that cause a breakdown of supporting structures or of lines that provide commercial communication, the carrier system of communication, depending upon the transmission line for the guidance of high-frequency current, was still operative.

From a reliability standpoint therefore, we believe, that carrier, properly applied, installed, and maintained, provides over our system a continuity of service economically possible by no other means of communication.

Based on the results of a traffic check made on a channel with 11 sets, over 9 week days during hours 8 to 12 a. m. and 1 to 5 p. m. the following is obtained:

(a) Average number of times channel was used per hour, 14.1.

(b) Average duration of a conversation, 1 min., 39 sec.

(c) Percentage of time channel was in use, 38.5 per cent.

By systematic scheduling it is believed that double the traffic shown here can be conveniently handled over a single channel.

Nine failures of coupling capacitors have occurred so far, and in all these cases the protective system used between the power conductors and the equipment and operators has functioned correctly and no damage or injury of any kind has occurred to equipment or operators. With the placing of all lead-in conductors underground the present extremely small hazard will be further reduced. The hazard is surely less than that existing in connection with the use of telephone circuits strung on transmission lines or even of some commercial overhead circuits.

In the complete paper the entire carrier communication system is described in detail, the principles of operation of various carrier communication systems developed by manufacturers are outlined, the component parts of the system such as coupling, transmitting, receiving and power supply systems are analyzed and experiences with each given. The general system arrangement, including description of communication zones established by means of frequency channels and arrangements for communication between zones is set forth, and also data is given covering the cost of installation, comparison of costs with other systems of communication, extent of maintenance required and the costs of same, traffic on the system, safety, and reliability. An extensive bibliography is also included.

Abridgment of

Stability of Synchronous Machines

Effect of Armature Circuit Resistance

BY C. A. NICKLE* and C. A. PIERCE*

Associate, A. I. E. E. Non-member

Synopsis.—*The theory of synchronous machines as developed by Doherty and Nickle*[1] *has been extended to include a determination of the effect of armature circuit resistance on damping torque. Equations are developed for the damping torque of synchronous machines in general, i. e., both the salient-pole and round rotor types. These equations assume an exciting winding in the direct axis and an amortisseur winding in the quadrature axis, and further assume that all damping is due to currents induced in these two windings. The effect of an amortisseur winding in the direct axis is not considered because its damping action at the low frequency of hunting is small compared to that of the exciting winding. It is shown that the damping torque of any synchronous machine can become negative, giving instability, if the armature resistance is increased beyond a critical limiting value. This fact has been known,*[2] *but an actual determinination of the value of the critical resistance in terms of constants of the machine has not, to the authors' knowledge, been available. For a salient-pole generator with normal excitation and no amortisseur winding this value, is*

$$r = x_q \tan \delta'$$

where r is armature circuit resistance,† x_q *is quadrature synchronous reactance, and* δ' *is the steady-state displacement angle. If r is less than the critical limiting value, the damping torque is positive; if greater, negative.*

The damping of a generator increases in the positive direction with increase in load. Thus a salient-pole generator with amortisseur winding, if stable at no load, will be stable under any steady load within its steady-state power limit. With $\delta' = 0$, *and normal excitation, the critical limiting value of armature resistance for a machine with an armotisseur winding is*

$$r = \sqrt{b\,d + \frac{d}{b}\,(x_d - a)^2}$$

where x_d *is the direct synchronous reactance and a, b, d are constants depending upon the design of the machine. This formula is useful for determining the constants of an amortisseur winding which would prevent sustained or cumulative oscillations of a generator.*

The analysis also shows that a round-rotor generator with identical field windings in the direct and quadrature axes may be made unstable by too much resistance in the armature circuits. This fact had been previously established by Dreyfus.[2]

The relations for inherent stability in synchronous motors are not so simple as for generators, but definite relations involving armature resistance will be found in the article.

The mathematical analysis is checked with laboratory experiments.

* * * * *

Introduction

THE problem of sustained and cumulative oscillations due to an impressed periodic exciting torque has been fully treated in the literature of synchronous machines.[3] As shown by Dr. Ludwig Dreyfus,[2] it is further known that sustained and cumulative oscillations can occur without the presence of a periodic exciting torque. He called these oscillations self-excited because they can be started by an impulse of momentary duration and once started, become self-sustaining provided conditions favorable to such oscillations exist in the circuits of the machine.

His method of attack was to set up and solve the differential equations for the magnetic fields of a round-rotor machine under the conditions of small forced oscillations. The final equations of this analysis are based on a round-rotor machine with a damping winding in the quadrature axis having the same constants as the d-c. field winding. By means of these equations, he showed that self-excited oscillations may be set up; *i. e.*, that negative damping is possible. He showed furthermore that the conditions favorable for negative damping are high excitation, low-line frequency, and a large value of armature resistance. In the conclusion to the paper, it is stated that the oscillations of the exciting current due to transformer action between armature and field help to stabilize the machine, and a well-designed amortisseur winding in the quadrature axis will completely suppress the self-excited oscillations.

While Dr. Dreyfus initially considers both salient-pole and round-rotor machines in his paper, the part of the mathematical analysis dealing with self-excited oscillations in an actual machine is based on a machine with a uniform air gap. It is desirable to extend the analysis to include salient-pole machines. The necessity for considering this type is proved by engineering experience. Certain instances of troublesome hunting with salient-pole generators have come to notice from time to time that were difficult to explain. It was believed that too large armature resistance was to blame, but no analysis of the effect of this resistance was available with which to check the belief. This paper is the direct outcome of this problem. It takes up the mathematical analysis and solution for the effect of armature circuit resistance on damping torque of the

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†Armature circuit resistance includes the resistance of armature phase and line wire back to the system bus. Likewise, synchronous reactance includes the reactance of line wire as well as the synchronous reactance of the phase. These quantities will usually be referred to as armature resistance and synchronous reactance.

1. For references see Bibliography.

Presented at the Great Lakes District Meeting of the A. I. E. E., Chicago, Ill., December 2-4, 1929. Complete copy upon request.

salient-pole machine, and includes experimental verification of the mathematical solution, as well as application of the conclusion to a practical problem.

The mathematical analysis is based on the vector diagram rather than on the original differential equations for the machine, and is an extension of an Institute paper[1b] on torque-angle characteristics of synchronous machines under transient conditions. In the paper just referred to, equations for both synchronizing and damping torque were developed for salient-pole machines based on the assumption of zero armature circuit resistance. This assumption, in so far as it affects torque angle characteristics, had been justified in an earlier Institute paper[1a] by the same authors. The mathematical analysis will now be extended to show the effect of armature circuit resistance on damping torque.

In the mathematical analysis, the synchronous machine is considered to have a main-field winding in the direct axis and a damping winding in the quadrature axis. Although the ordinary amortisseur winding gives damping in both axes, its effect in the direct axis is neglected, since at the low frequency of oscillation usually encountered, the damping of the main-field winding predominates. This method of attack gives a solution that can be readily simplified to apply when there is no amortisseur winding. Since a great many machines have no amortisseur winding, this case has been considered in some detail.

Damping due to means other than the main-field winding and the amortisseur winding is not considered. Any external damping that may exist can be added to the inherent damping of the two windings if it is desired to determine the total damping acting on the rotor.

Saturation of the magnetic circuits is not considered. To include the effects of saturation would unduly complicate the mathematical analysis, if it did not make a solution impossible.

Mathematical Analysis

The mathematical analysis of the problem gives a formula for the damping torque of the synchronous machine considered. The armature circuit resistance appears in this formula in rather a complicated manner, so that the relation between damping torque and this resistance is not immediately apparent. The formula is much simplified, however, by eliminating the effect of the amortisseur winding in the quadrature axis; *i. e.*, by considering a salient-pole machine in which all damping is due to current induced in the main-field winding. The formula for damping torque in this case is

$$T_d = \frac{B\, b\, e\, (r^2 + x_d\, x_q)\, (x_q \tan \delta' - r) \cos \delta'}{s\,[\,\{b\, x_q\}^2 + \{r^2 + x_q\,(x_d - a)\,\}^2\,]} \qquad (61)$$

The quantities e, a, b, x_d, x_q, r, s, and $\cos \delta'$ are all positive. Thus the sign of the damping torque is determined by the quantities B and $(x_q \tan \delta' - r)$. Hence Equation (61) for damping torque of a synchronous machine can be rewritten as

$$T_d = K\, B\, (x_q \tan \delta' - r) \qquad (62)$$

where K is a positive constant including various constants of the machine.

The value of the constant B in Formula (61) is determined as

$$B = \frac{e\,(x_q \sin \delta' + r \cos \delta')}{r^2 + x_d\, x_q} + \frac{2\, r(r^2 + x_q^2)(e_d' - e \cos \delta') + 2\, r^2 (x_d - x_q)\, e \sin \delta'}{(r^2 + x_d\, x_q)^2} \qquad (47)$$

Inspection of Equation (47) shows that the quantity B can become negative in value with positive values of displacement angle δ' if the nominal voltage e_d' is sufficiently small, *i. e.*, if the excitation is sufficiently reduced. However, under usual conditions of operation as a generator the quantity B is positive in value. Thus Equation (62) shows that a generator without amortisseur winding will be negatively damped and will oscillate at no load unless stabilized by positive damping external to the main-field winding. The relation that must exist in order for the machine to show inherent positive damping, *i. e.*, damping due to the main field winding, is

$$r < x_q \tan \delta' \qquad (63)$$

The critical value of resistance is $r = x_q \tan \delta'$; if the resistance is greater than this value, the inherent damping becomes negative in value.

The case is somewhat different for a synchronous motor. Inspection of Equation (47) shows that the constant B may be positive or negative in value depending on the values of the armature resistance r, displacement angle δ', which is negative for a motor, and the amount of excitation, which determines e_d'. With negative values of δ', the quantity $(x_q \tan \delta' - r)$ is negative in value. Thus for a motor in which all damping is due to current induced in the main field winding, the damping will be positive or negative as determined by the value of B. If B is negative, the damping is positive; if B is positive, the damping is negative; (Refer to Fig. 7). Further inspection of Equation (47) shows that the character of the damping in a motor also depends on r, the armature resistance.

Graphical Illustration of Results of Mathematical Analysis

Several curves have been determined by means of the preceding equations to show the effect that armature resistance has on damping torque of a synchronous machine which is connected to an infinite bus and carries a constant load The machine constants were chosen for illustrative purposes alone, and do not represent an actual machine. The two curves in Fig. 3 show the variation of damping torque for a synchronous generator

which has no amortisseur winding, when the armature resistance is varied from zero to 0.75; *i. e.*, to 75 per cent. The values in the per unit system[4] of the constants which were used for the curves are $s = 0.02$, $e_d' = 1 = e$, $x_d = 1$, $x_q = 0.5$, $x_{md} = 0.8$, $X_{lda} = 0.2$, $\delta' = 15$ deg. Curve A is for a main field resistance of $R_{da} = 0.05$ and Curve B is for $R_{da} = 0.01$. These curves are computed by means of Equations (**61**) and (**47**).

Since the damping for the conditions of Fig. 3 is caused by absorption of power in resistance loss due to current induced in the main field winding, it is to be

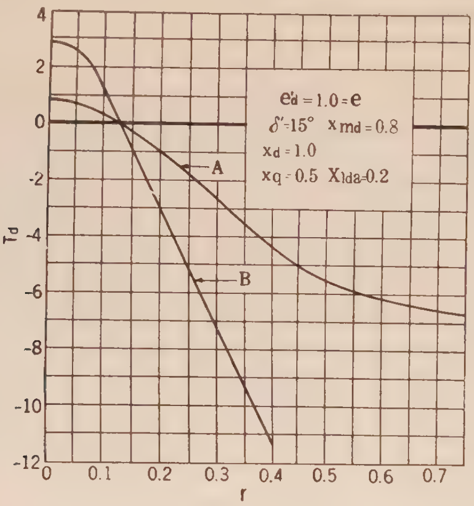

Fig. 3—Curves of Damping Torque as a Function of Armature Resistance—No Damping Winding

(A) Field resistance, R_{da}, in armature terms = 0.05
(B) Field resistance = 0.01

expected that less resistance in the field circuit will give greater damping, as shown by the two curves. But until Equations (**62**) and (**63**) were derived, there had been no way so far as the authors know of determining, that the damping of a salient-pole machine would become negative in value for an armature resistance greater than a certain critical value which the analysis shows to be $r = x_q \tan \delta'$. The value of main-field resistance is important in determining the amount of damping but does not determine whether it is positive or negative in value; this is determined by the value of the armature resistance.

The critical armature resistance for the constants assumed is $r = 0.134$, which is a much larger value than would be found in the windings of an armature, but is not an unusual value when the line back to the infinite bus is considered. Furthermore, Equation (**63**) shows that the critical value is increased proportionally to the increase in the tangent of the steady-load displacement angle. Thus a generator may hunt badly on light loads and yet run satisfactorily under larger loads.

Fig. 7 is based on Equations (**61**) and (**47**); but the four curves are for different amounts of excitation; namely, $e_d' = 0.25$, $e_d' = 0.5$, $e_d' = 1$, and $e_d' = 1.5$. The armature resistance is $r = 0.1$ for all the curves. These curves show that the constant B is a positive quantity for all positive values of the load angle δ' and for all the values of excitation noted; but for negative load angles the constant B is positive or negative in value depending on load angle and excitation. The sign of B does not determine the sign of T_d with the machine run as a generator, but does determine the sign of T_d with the machine run as a motor. The sign of T_d with the machine a generator is determined solely by the value of r, as already discussed.

Experimental Verification of Mathematical Analysis

A number of tests were run in the laboratory to check the theoretical formulas found by means of the mathematical analysis. Some of the tests were quali-

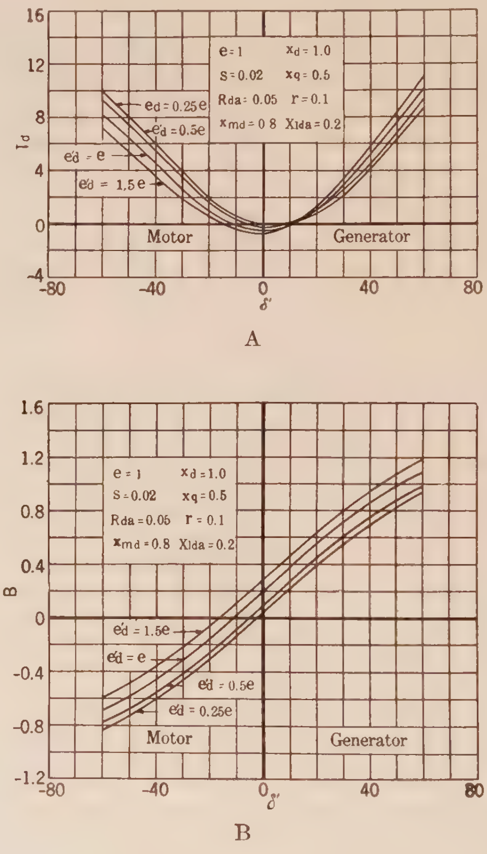

Fig. 7—Curves of Damping Torque and the Factor B as Functions of Load Angle with Excitation as a Parameter. Constant Armature Resistance and No Amortisseur Winding

tative and some were quantitative. As an illustration of the qualitative tests, Figs. 10 and 11 show oscillograms of armature and field currents for a three-phase, four-pole, 15-kw., 1800-rev. per min., 220-volt salient-pole synchronous motor direct-connected to a d-c. generator which was loaded with a resistor. The motor was connected to a bus of relatively large power capacity, and the excitation was varied through wide limits, keeping the input to the motor constant at 6 kw.

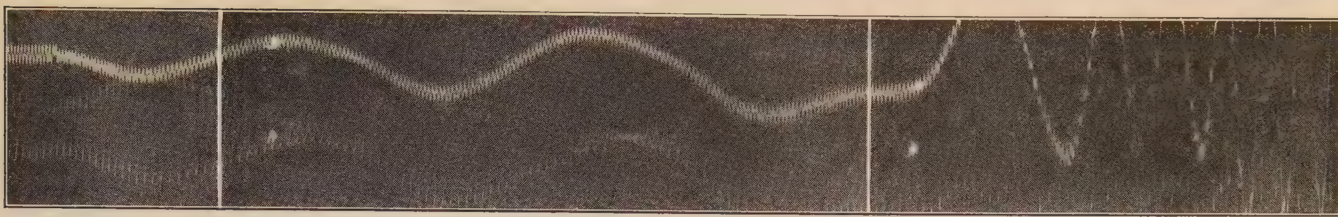

Fig. 10—Oscillogram Showing Cumulative Hunting Produced by Introduction of Resistance in the Armature Lines of a Motor

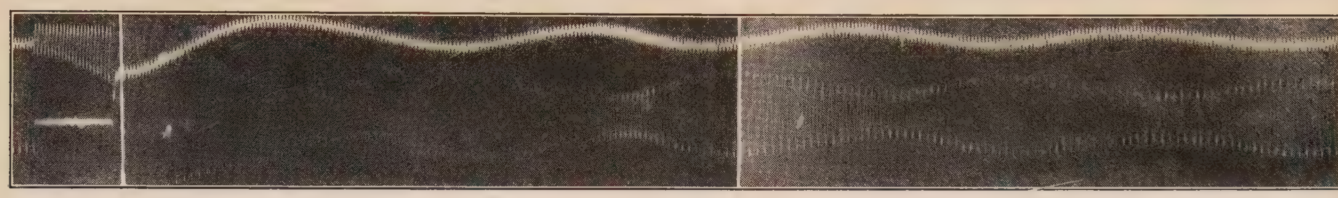

Fig. 11—Oscillogram Showing Effect of Excitation upon Damping

Conditions the same as for Fig. 10 except that excitation was reduced from 1.1 to 0.733.

curve (a)—armature current
curve (b)—field current

The set was found to be exceedingly stable with a motor excitation of 0.458, the per-unit system,[4] this excitation giving such high positive damping that an initial swing of hunting was damped out aperiodically. With an excitation of 0.733, the set ran with sustained hunting, as shown in Fig. 11. With the excitation raised to 1.100, the motor could not be kept on the bus, dropping out of step within a few seconds, as shown in Fig. 10. These results check Fig. 7A where a constant load on the motor is represented by a constant value of δ'.

Summary

The results given in the paper show that the calculated curves of negative damping under various conditions of loading, excitation, etc., are in essential agreement with results obtained from test. The calculated curves are correct in form and the magnitudes check test values reasonably well to allow of practical accuracy in the use of the general expressions developed in the paper. More recent tests further confirm the theoretical formulas.

This article furnishes an explanation for those many cases encountered in the field in which machines cannot be kept in synchronism when operated over long lines, or are unstable for no apparent reason.

Acknowledgments

The authors gratefully acknowledge the valuable assistance of Messrs. S. R. Pritchard, Jr., R. C. Small, and S. A. Loukomsky in the preparation of experimental data on the salient-pole machine. They also wish to acknowledge the helpful suggestions of Messrs. R. E. Doherty and R. H. Park.

Nomenclature

Peak values are used for voltage and current. Primed quantities indicate steady-state values. The symbol Δ indicates variation of the quantity which follows the symbol. Per unit values are used for all equations and numerical work.

e = terminal voltage.

e_d = nominal voltage due to excitation in the direct axis.

s = angular velocity of modulation.

r = armature circuit resistance; includes resistance of line wire, back to the infinite bus.

x_d = synchronous reactance, direct axis; includes reactance of line wire back to the finite bus.

x_q = synchronous reactance, quadrature axis; includes reactance of line wire back to the infinite bus.

T_d = damping torque.

δ = angular displacement between the axes of rotor and rotating magnetic field; a plus angle indicates generator; a negative angle indicates motor.

a, b = constants inherently positive in value which are determined by s and design constants of the synchronous machine.

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The Calorimetric Study of the Arc

BY P. P. ALEXANDER[1]

Member, A. I. E. E.

Synopsis.—*The present paper describes an attempt to determine the distribution of energy in the electric arc by the calorimetric method. The total energy input to the arc was measured by a specially calibrated watthour meter. The energy dissipated at the anode and at the cathode was estimated by the temperature rise of the electrodes, which was measured by mercury thermometers. In experiments with the iron, copper, and carbon arcs, the anode and cathode were of the same weight and shape and were provided with an identical heat insulation. Since the ratio between the energies dissipated at the anode and at the cathode was made independent of the losses by radiation and the absolute values of energies involved, its determination was made with sufficient accuracy. In the case of iron or copper arcs in air this ratio was found to be practically unity. The presence of different fluxes alters the distribution of energy between the anode and cathode. In the case of an arc maintained between graphite electrodes, the energy at the anode was much higher than that at the cathode.*

* * * * *

INTRODUCTION

THE total energy input to the arc can be accurately determined by means of the usual measuring instruments. However, when the electric arc is used as a tool for electric welding, it is useful to know not only the total energy in the arc, but also the distribution of that energy between the anode and cathode. This information is desirable for the purpose of determining the conditions for the most rapid melting of the electrode and for the effective fusing of the plates to be welded.

As has been shown by many physicists, the distribution of energy in the arc can be calculated. The heating of the cathode is due to the bombardment of its surface with positive ions which acquire a considerable velocity by moving through the cathode fall. This energy is increased a small amount by the heat of neutralization of these ions on the surface of the cathode, by a certain amount of heat evolved by oxidation reactions taking place either on its surface or in its vicinity, etc. The most important factors which determine the heating of the cathode are the ratio between the positive and negative ions in the immediate vicinity of the surface of the cathode, and the value of the cathode fall. These factors have been determined with precision for arcs maintained between non-vaporizing electrodes in such gases as helium, argon, and mercury, but corresponding values for an iron arc maintained in air are not known as yet with certainty. The anode is heated principally by the bombardment and by the absorption of released latent heat of condensation of the incoming electrons. We must also know for our calculations the value of the anode fall and the ratio between the electrons and the positive ions. However, at the present time, it is practically impossible to calculate with sufficient approximation the heat evolved at the cathode and the anode of a short iron arc of any considerable intensity.

The experimental method of determining the distribution of energy in such an arc is, therefore, the only alternative. Although it cannot claim great precision,

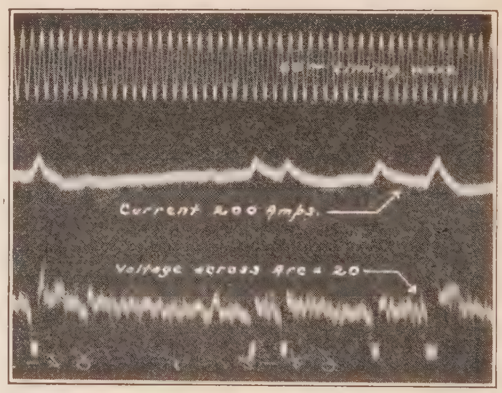

FIG. 1—OSCILLOGRAM OF ARC CURRENT AND VOLTAGE

in the case of an iron arc of a type similar to that used in welding, it gives some useful information on this subject.

A great difficulty in making the necessary measurements is the inherent peculiarity of the iron welding arc. As the oscillogram in Fig. 1 shows, the voltage across the arc is a pulsating voltage of an average frequency of 300 cycles. When a molten globule passes across the arc from the rapidly melting electrode to the weld, the

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Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Printed complete herein.

arc is momentarily short circuited and its voltage drops practically to zero.

Since the molten metal from the electrode is deposited into the opposite crater, all the energy consumed in melting the electrode is mechanically transferred to this crater. In other words, the energies put into the cathode and the anode are periodically added together. Except for radiation and other losses, the total energy

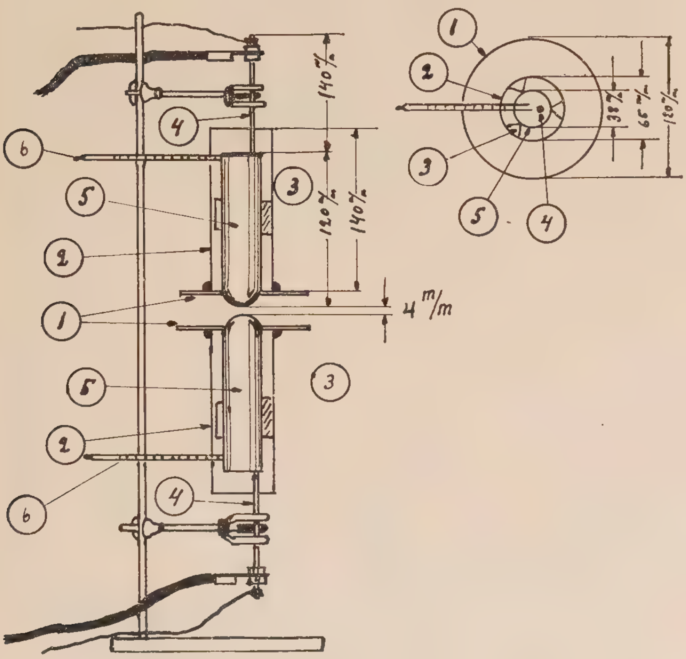


Fig. 2—Arc Electrodes Used in Tests

1. Asbestos, 3 mm. thick
2. Cylinder of 0.12 mm. polished copper
3. Cork spacer
4. Brass rod
5. Electrode, polished steel cylinder, 38 mm. in diameter
6. Thermometer

of the arc is eventually transferred into the weld. The speed of welding, however, depends not only on the total energy of the arc, but also on that part of the total energy of the arc which is utilized in melting the welding wire. In other words, it depends on the distribution of energy in the arc.

Experimental Method

As a first approach to the solution of this problem, the following method was developed to measure the ratio between the energy input of the anode and the cathode. The underlying thought in planning these experiments was to approach as near as possible to the conditions under which the iron arc is used as a welding tool and yet to eliminate all the unessential factors which might obstruct the solution of the problem. As has been mentioned above, one of these factors is the short circuiting of the arc by the molten globules.

The first series of tests, therefore, was conducted under conditions in which the short circuiting of the arc did not take place. As Fig. 2 shows, the anode and cathode consisted of small steel cylinders of identical shape and weight. They were polished to reduce the losses by radiation and except for the small surface at one end, were protected by an efficient heat insulation, consisting of a cushion of dry air enclosed in a cylinder of thin polished copper sheet. Near their outer ends these electrodes were provided with holes in which thermometers of the same calibration as to heat capacity and sensitivity were inserted.

As Fig. 3 shows, direct current was supplied by a constant potential source of 275 volts. A heavy resistance balance supplemented by considerable reactance connected in series insured a supply of current, practically independent of small variations in the voltage of the arc. Also, since the heat capacity and heat insulation of the anode and cathode were practically identical, variations of voltage and current in the arc during the observation would affect both electrodes equally. In other words, the error from this cause may be introduced in estimating the total input energy but not in determining the ratio between the energy input of the anode and cathode. The time of the burning of the arc was purposely made very short, ranging from 30 to 300 seconds. This resulted in a comparatively small temperature rise, and, therefore, small losses by radiation or conduction. In most of the experiments, the difference between the total measured energy input to the arc and the sum of the energy measured at the anode and at the cathode was less than 20 per cent, which indicates that these measurements were sufficiently exact for the purpose in view.

The first series of experiments was made with a constant distance of 4 mm. between the electrodes. This distance was adopted because the average length of the iron welding arc is usually of this value. In successive tests, the currents were increased by steps from 30 amperes up, until at approximately 135 amperes there was a melting of the tips of the electrodes, which periodically shorted the arc. At this point, the molten

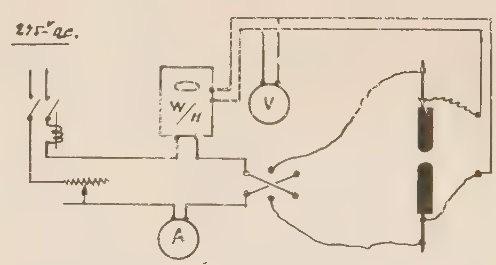


Fig. 3—Circuit Connections for Tests

metal bridged the gap for a fraction of a second every two or three seconds. In every case, the bridge of molten metal was disrupted by the short circuit current, and the parts of the disrupted globule were then separated by the equal surface tension of the molten metal on the anode and cathode.

No transfer of metal from the upper electrode to the lower one was observed. This condition of the test

approached the conditions met in the metallic welding arc, yet did not contain the factors obscuring the real picture of the distribution of energy in the arc. The temperature curves shown in Figs. 4, 5, and 6 indicate that in all these experiments the energy delivered to the

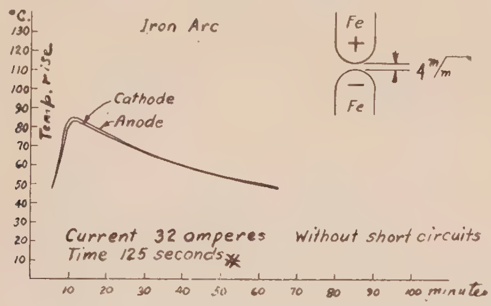


Fig. 4

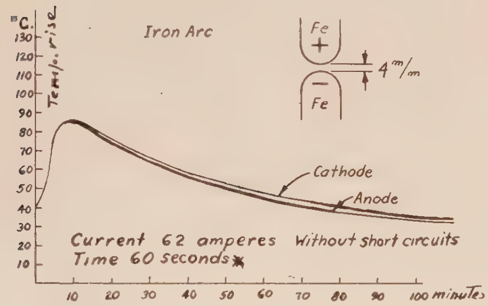


Fig. 5

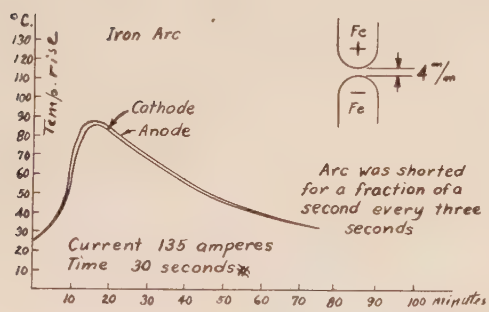
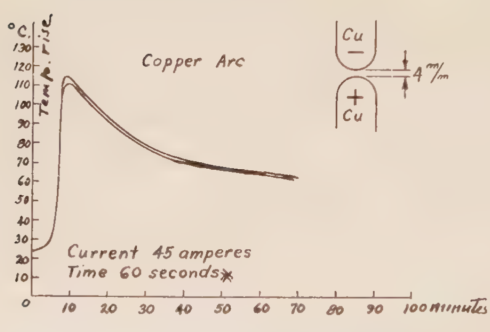


Fig. 6



Figs. 4 to 7—Anode and Cathode Temperature Curves

*Time of burning of the arc

cathode was practically equal to that received by the anode.

Fig. 7 shows the temperature curves of the copper arc. The measured ratio between the anode and cathode energies was almost equal to one.

The second series of experiments was conducted for the purpose of determining the influence of the relative position of the anode and cathode on the distribution of energy in the carbon or iron-carbon arcs.

Table I gives the results of these measurements. The figures given in this table are not averages but are individual tests. However, prior to the tabulation of

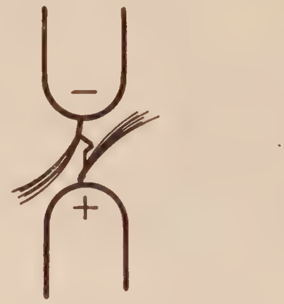


Fig. 8—Drawing Showing Hot Gas Blasts and Arc Core

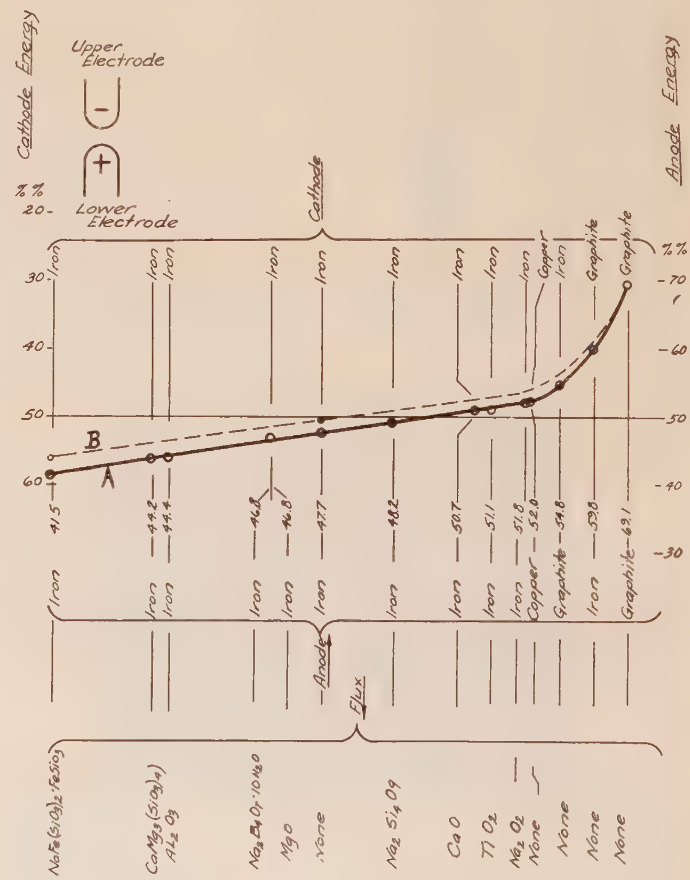


Fig. 9—Curves Showing Ratio Between Anode and Cathode Energies for Various Fluxes and Electrodes

these results, every test was repeated several times and it was ascertained that the reported figures represent the most accurate observation for each type of arc.

The total energy developed in the arc was measured by counting the number of revolutions of the aluminum disk connected with the armature of the watthour meter. Since this instrument was specially calibrated

TABLE I

Test No.		1	2	3	4	5	6
Anode		Iron	Iron	Graphite	Graphite	Graphite	Iron
Cathode		Iron	Iron	Graphite	Graphite	Iron	Graphite
Polarity of the upper electrode		−	+	−	+	−	−
Total energy developed in the arc, in g-cal		16,400	16,400	11,400	13,100	9,840	16,400
Energy measured at the anode, g-cal		6,380	6,800	7,010	8,400	5,160	7,920
Energy measured at the cathode, g-cal		7,000	6,430	3,140	3,760	4,250	5,330
Sum of anode and cathode energies g-cal		13,380	13,230	10,150	12,160	9,410	13,250
Losses by evaporation, radiation, etc., in %		18.4	19.3	11.0	7.2	4.4	19.3
Distribution of energy in %	Anode	38.9	41.4	61.5	64.1	52.4	48.2
	Cathode	42.7	39.3	27.5	28.7	43.2	32.5

for the voltage of the arc, the error in determining the total energy was probably less than 1 per cent.

As has already been stated, the energy received by each electrode was estimated from temperature rise registered by specially calibrated mercury thermometers. The error in these estimates was probably less than 0.3 of one per cent of the energy input into each electrode.

The losses by radiation were estimated by tracing the temperature curves for the cooling electrodes. However, since the losses were the same for both electrodes, they did not enter into the calculation of the ratio between the anode and cathode energies. The total losses from the arc shown in Table I were obtained by substracting the measured anode and cathode energies from the total energy input to the arc. These losses are due in part to the evaporation of atoms from the cathode and anode spots of the arc.

A close observation of the arc, which can be made more conveniently with longer arcs of 10 mm. to 12 mm., reveals the presence of two distinct blasts of hot gases issuing from the cathode and anode with considerable velocity. These streams exert a considerable repulsive force upon each other and undoubtedly consist of streams of neutral atoms.

The arc core appears as a narrow bright bluish band within these blasts of hot gases. Yet, it does not constitute an integral part of the blasts, and, under certain conditions, (Fig. 8) may be pushed out of the envelope of hot gases. It could be observed, then, as a bright bluish band bridging the air space between the two blasts or jets of hot gases, tending, like a spring, to unite them. This tendency of the arc core to locate itself within the blast of hot gases is due to the greater ease of ionizing those gases than the air.

Table I also shows that in the case of an iron arc, the upper electrode, regardless of its polarity, receives more energy than the lower one. This is due to the influence of the ascending stream of hot gases. If the necessary correction is made, the ratio between the energy developed by the arc at the anode and cathode of an iron arc is almost unity and can be expressed in per cent as 49.5 per cent for the anode and 50.5 per cent for the cathode.

The third series of experiments was conducted for the purpose of determining the influence of various fluxes. Fig. 9 shows how various fluxes alter the distribution in the arc.

Conclusion

The experiments described above should be considered only as the first approach to the solution of the problem of the distribution of energy in the welding arc. It is realized that other factors, such as unequal heat capacity of the electrodes, radiations from the larger positive crater, etc., will have considerable bearing on the heat distribution between the electrodes. It may be concluded, however, that in an iron arc, the energy developed at the surface of the anode is practically equal to that developed at the cathode.

It should be observed that the above results indicating equal distribution of energy in the iron arc are not in contradiction with the well-known fact that in arc welding the electrode melts faster when it is made positive. Accurate measurements of the arc voltage and the energy of the arc have shown that the cause of the faster melting resides in the direction of the blast of hot gases. The blast of hot gases is stronger from the cathode spot; therefore, when the electrode is made negative, the blast of hot gases from the electrode is more powerful than from the anode. The resultant blast is, therefore, directed downward, which causes greater heating of the metal around the positive crater. When the electrode is made positive, the resultant blast of hot gases is directed from the weld. It bathes the tip of the electrode like a hot flame, producing an effect equivalent to preheating. Also, when the electrode is made positive, the arc is not quite as stable as when it is negative. The negative side of the arc wanders. The arc voltage is greater, and, therefore, greater energy is developed in the arc.

When the arc is made quite stable and of exactly the same current and voltage and the electrode is protected from the blast of hot gases, the rate of melting of the electrode is practically the same, whether the electrode is made negative or positive. It may also be seen how different fluxes placed on the anode may alter the distribution of energy in the arc.

A directional marker beacon has been installed at Mitchel Field, Long Island, for use in connection with fog landing experiments. This marker beacon is employed in conjunction with the directive localizing beacon. At Mitchel Field it is used for marking out one edge of the landing field.

Abridgment of

Inversion Currents and Voltages in Auto-Transformers

BY A. BOYAJIAN[1]

Fellow, A. I. E. E.

Synopsis.—*Line grounds on the secondary of an auto-transformer, fed from a grounded system, tend to invert the neutral of the auto-transformer. If the auto-transformer is isolated, this may lead to larger voltages, and if grounded, to larger currents than what would ordinarily be expected. The analysis of an important installation (75,000-kv-a., three-phase units at Detroit) is given below, for various possible connections and conditions of operation.*

Features of the analysis are: (A) A novel theory and method of auto-transformer circuit representation was developed to handle some aspects of this problem that otherwise appeared elusive.[2] *The method is applicable to all networks involving auto-transformers. (B) The rather startling fact is brought out and explained that fault currents to ground on the secondary lines of an auto-transformer may be larger when stepping-up than when stepping-down. The prediction has been verified by test.*

* * * * *

Introduction

The use of auto-transformers in transmission circuits involves much more complicated problems than the use of straight transformers. It is very desirable to clarify the solutions of such problems so as to enable consulting and operating engineers to ascertain readily the characteristics of such circuits and the effect of various modifications. This study was undertaken in connection with some 75,000-kv-a. auto-transformers now installed in the Detroit-Edison system, and this concrete application of the theory makes the presentation the more interesting and instructive.

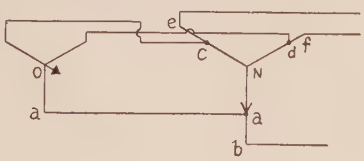


Fig. 1—Diagram of Grounded Generator Feeding an Isolated Step-Up Auto-Transformer

Meaning of "Inversion"

Fig. 1 shows a grounded generator feeding an isolated step-up auto-transformer. Under normal conditions, the potential of N is at the center of gravity of the vector diagram, and hence coincides with that of the neutral of the generator and ground.

If terminal b becomes grounded (Fig. 2), the potential of b is moved to ground to correspond to o; and, since the potential of a is definitely fixed by the generator, the movement of b (to where N was formerly) reverses the direction of the voltage $a\ b$ as will be seen in Fig. 2. The reversal of the excitation on $a - b$ reverses the entire leg $N - b$ and throws N outside of the triangle of line voltages. Hence the term "inversion." It appears that L. F. Blume first predicted this phenomenon and called it to C. P. Steinmetz's attention, whereupon the latter christened it as "inversion" of the neutral.

Besides reversal, a change in magnitude also takes place in the excitation of $a - b$ because while formerly (in Fig. 1) it was determined by the auto-transformer ratio, now it has to be equal to $o - a$ regardless of what the auto-transformer ratio may be.

Vector Diagram of Inversion

The vector diagram of Fig. 2 is drawn as follows: The points a, b, c, d are fixed directly by the generator; $a - N$ is drawn equal to $a - b$ times the ratio of the common turns to the series turns; $N - c$ and $N - d$ are then drawn extending to e and f respectively, making the ratio of $e - c$ to $c - N$ (or $f - d$ to $d - N$) that of the series to common turns. The excitation of the faulty leg in terms of normal excitation is $E_{lv}/(E_{hv} - E_{lv})$—that is, the low-voltage line voltage divided by the difference between the high- and low-line voltages.

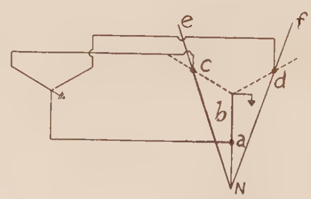


Fig. 2—Same as Fig. 1 with Terminal b Grounded

Obviously, as the high- and low-line voltages approach each other, this overexcitation is increased. Thus, if the difference between high- and low line voltages is 10 per cent, the faulty leg becomes excited 10 times normal.

Considering the circuit from the standpoint of short-circuit currents, it will be seen that there will be no short-circuit currents in the ordinary sense, but the over-excitation of the auto-transformer may cause exciting current rushes comparable to short-circuit currents, depending on the degree of overexcitation.

The connection analyzed in Figs. 1 and 2 is obviously not a desirable operating connection, especially for booster auto-transformers. It was chosen merely for illustration on account of its simplicity and accentuated overvoltages. Operative connections avoid these excessive inversion voltages, but are accompanied by inver-

1. Transformer Engg. Dept., General Electric Company, Pittsfield, Mass.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 27-31, 1930. Complete copy upon request.

sion currents. Ten such cases are analyzed below with respect to currents and voltages, and the results are arranged in Table I.

Discussion of Cases

The circuit connections and ground and fault locations for the ten cases are shown in the first column of Table I. The corresponding zero-sequence impedance networks are shown in the second column. The positive and negative sequence networks are not shown because they are obvious. The first four cases in which the delta tertiary winding is omitted, are of only theoretical interest for comparison, as the transformers actually have tertiary delta windings. For this same reason, these four cases have been simplified assuming that the zero sequence impedance of the auto-transformer (194 per cent for the full winding) is high enough to compel all the zero sequence current to flow through the generator. The resistances of these circuits being very small compared with the reactances, the impedances are treated as reactances.

TABLE I.
Inversion Currents and Voltages in Auto-Transformers

SYSTEM CONNECTION GEN. AUTO.	EQUIVALENT ZERO-SEQUENCE NETWORK (ONLY ONE LEG SHOWN)	CURRENTS				VOLTAGE TO GROUND UPPER LIMITS			
		FAULT & SERIES WDG	COMM. WDG	TERTIARY	GEN.	GEN. NEUT.	AUTO NEUT	L.V. LINES	H.V. LINES
1.	j5.7, j9.68	8,220 4.85 × BASE I	9,320	0	17,600	NORMAL	NORMAL	NORMAL	NORMAL
2. (1Ω)	j5.7, j9.68, 34.4	7,180 4.25 × BASE I	8,140	0	15,300	7,180	7,180	14,100	21,800
3. (¼Ω)	j5.7, j9.68, 39.2	6,920 4.1 × BASE I	7,870	0	14,820	3,700	0	10,540	22,800
4. (1Ω)	j5.7, j9.68, 44.4	6,660 3.94 × BASE I	7,570	0	14,200	0	7,570	NORMAL	23,400
5. (1Ω)	j1.25, j4.62, j16.32, j7.67, 34.4	7,650 4.52 × BASE I	7,780	0.246 × BASE 0.986 × CAP	15,400	7,650	7,650	14,570	22,400
6. (¼Ω)	j1.25, j4.62, j16.32, j7.67, 8.6	7,480 4.42 × BASE I	4,420	1.32 × BASE 5.3 × CAP	11,600	1,485	0	8,400	14,800
7. (1Ω)	j1.25, j4.62, j16.32, j7.67, 34.4	7,400 4.38 × BASE I	5,600	0.776 × BASE 3.1 × CAP	12,987	7,400	7,400	14,000	22,000
8. (1Ω)	j1.25, j4.62, j16.32, j7.67, 34.4	6,470 3.82 × BASE I	4600	1.27 × BASE 5.1 × CAP	9,200	6,470	6,470	13,400	21,200
9	j1.25, j4.62, j16.32, j7.67	7,220 4.26 × BASE I	5,130	1.42 × BASE 5.68 × CAP	10,270	6,900	0	12,000	25,000
10.	j1.25, j4.62, j16.32, j7.67	8,560 5.06 × BASE I	6,470	0.895 × BASE 3.58 × CAP	15,000	0		6,400	13,600

By the well-known general formula, applicable to all cases of single-phase, line-to-neutral short-circuits on three-phase circuits,

$$I_{fault} = \frac{3\,E}{Z_0 + Z_1 + Z_2}, \text{ or}$$

$$= \frac{300 \times \text{base current}}{\%\,I\,Z_0 + \%\,I\,Z_1 + \%\,I\,Z_2}$$

Since the positive and negative sequence networks are obvious, the main problem is to trace and evaluate the zero-sequence networks.

Some of these cases (Cases 5-10) involve zero-sequence networks that are both conductively and inductively interlinked, and are elusive to handle. It was for this purpose that a new theory of transformer and auto-transformer equivalent circuits was developed.

New Theory of Transformer and Auto-Transformer Circuits[2]

The conventional equivalent circuit of a transformer or auto-transformer is constructed on a one-to-one ratio basis, and therefore will not step-up or down any current or voltage. It is obvious, therefore, that a transformer in a network cannot actually be replaced by such an equivalent circuit without spoiling its fundamental function. This same observation holds true for our equivalent circuit representations of three-circuit transformers. All of these circuits are equivalent for certain purposes only, and no further. In analyzing complicated networks, however, we need an equivalent circuit which can actually completely replace the transformer or auto-transformer and perform all its functions. Such a circuit is derived by reasoning as follows:

The characteristics of a stationary outfit (which may be a transformer or auto-transformer) are completely determinable by measurements at its terminals, and therefore, such an outfit is completely replaceable by any other outfit which yields similar measurements at its terminals. Considering an auto-transformer with three terminals, a, b, and c, all the characteristics measurable at its terminals are that certain three impedance values Z_{ab}, Z_{bc}, and Z_{ca} exist among those three terminals; and, therefore, the outfit should be replaceable by any network having similar terminal impedance characteristics. The internal connection of the equivalent network may be anything we please, but Y and delta are the simplest alternatives. Accordingly, if we choose the Y equivalent, the values of the leg impedances Z_a, Z_b, Z_c in terms of the given

2. A thorough discussion of this theory was published in two articles in the *General Electric Review* for February, 1929. under the titles of "New Theory of Transformer and Auto-Transformer Circuits," by A. Boyajian, and" New Equivalent Circuits for Auto-Transformers and Transformers with Tapped Secondaries," by D. R. MacLeod. Through a strange coincidence, the two authors arrived at the same theory at the same time, while working on different problems, unaware of each other's work. Since the publication of these articles, Mr. W. D. Cannon called, the writer's attention to an article in the *Bell System Tech. Jl.*, Jan. 1925, p. 84, under the title of "Mutual Inductance in Wave Filters," in which transformer equivalent circuits, similar to those discussed here, are mentioned and credit is given in particular to Messrs. G. A. Campbell and W. L. Casper. The first foreshadowing of the idea is apparently in a paper by Campbell, *Cisoidal Oscillations*, A. I. E. E. Trans., Vol. XXX, Part II, pp. 873-909.

auto-transformer impedances Z_{ab}, Z_{bc}, Z_{ca} will be:

$$Z_a = (Z_{ab} - Z_{bc} + Z_{ca})/2 \text{ vectorially.}$$
$$Z_b = (Z_{bc} - Z_{ca} + Z_{ab})/2 \text{ vectorially.}$$
$$Z_c = (Z_{ca} - Z_{ab} + Z_{bc})/2 \text{ vectorially.}$$

In appearance, these formulas are similar to those used in three-winding transformers, but there is an important difference. In three-winding transformers, the impedances are reduced to a common kv-a. basis if they are in percentage form, and reduced to the same circuit if in ohmic form; whereas in the present case the ohmic values are actual (measured) ohmic values without any reduction or transformation, while percentage values are to be based on the same amperes and volts without changing the circuit, as will be illustrated below.

It will be seen on further study, that the current and voltage transformations accomplished in the auto-transformer by magnetic coupling, are accomplished in the equivalent network by shunt and series resonance.

Example. To avoid beclouding the main features of the discussion by unessential incidental details, we will ignore the losses of the auto-transformer in this illustration, and consider only the reactive constants. Let Fig. 3A represent a 1000-kv-a. auto-transformer, stepping up from 1000 volts to 2000 volts, with approximately 10 per cent magnetizing current and 10 per cent leakage reactance. Such an auto transformer can be completely replaced by the equivalent network shown in Fig. 3B. Any test applied to this network will show it to have the same characteristics as the specified auto-transformer. For instance, with a 1000-ampere unity power factor load across the secondary $H - N$, and 2000 volts maintained across it, the primary voltage will be $(1010 + j\,100)$ volts (which includes regulation), and primary current $(2000 - j\,200)$ amperes (which includes magnetizing current). The primary voltage includes correctly even the regulation caused by the magnetizing current.[3]

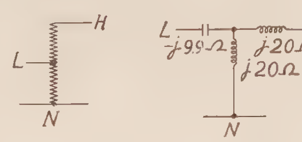


FIG. 3

a—DEVELOPED WINDING DIAGRAM

b—COMPLETE EQUIVALENT CIRCUIT REPRESENTATION

1000-kv-a., 1000-volt low-voltage, 2000-volt high-voltage auto-transformer with approximately 10 per cent magnetizing current and 10 per cent leakage reactance

The application of the foregoing theory and equivalent circuit to the problem of this paper is to the zero-sequence network in Cases 5-10, where the generator and auto-transformer zero-sequence paths are linked both conductively and inductively in a complicated manner, and the end sought is to replace the auto-transformer by an equivalent circuit, the branches of which have no mutual magnetic linkage, in order that the resulting network may be solved by elementary methods.

The details of all these calculations and other steps required in the preparation of Table I are given in the appendix to this paper.

RELATIVE MAGNITUDE OF HIGH- AND LOW-VOLTAGE FAULT CURRENTS

The fault current in a line-to-line short circuit on the secondary of an auto-transformer, is less on the high-voltage side than on the low-voltage side, being in the inverse ratio of the voltages; but this relationship does not hold true for line-to-neutral fault currents, especially when the fault current is limited entirely, or largely, by the zero-sequence impedances.

The auto-transformer steps up the voltage and also

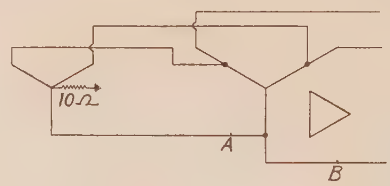


FIG. 4—DIAGRAM OF GENERATOR FEEDING AUTO-TRANSFORMER WITH TERTIARY DELTA

the positive and negative sequence impedances, but not the zero-sequence impedance; and therefore, when the zero-sequence impedance is dominant, short-circuit currents may be higher on the high-voltage side than on the low-voltage side. When the zero-sequence impedance is internal, these relations may be somewhat difficult to see, but when the zero-sequence impedance is external, the principle involved can easily be made clear, and the reasonableness of the more involved cases established.

Referring to Fig. 4, a line-to-line fault current, I_{fB}, at B will be smaller than a line-to-line fault current, I_{fA}, for a fault at A in the ratio

$$\frac{I_{fB}}{I_{fA}} < \frac{E_{LV}}{E_{HV}},$$

that is, less than the inverse ratio of the voltages, on account of the added auto-transformer impedance for faults at B. This is as we would expect it to be, but consider now the line-to-neutral fault currents:

The generator is grounded through a 10-ohm resistance representing 382 per cent zero-sequence impedance, purposely chosen high so that the generator and auto-transformer impedances may be negligible in comparison, and simplify calculation.

Will a line-to-neutral fault current (I_{fB}) at B be less than that (I_{fA}) for a line-to-neutral fault at A? Obviously,

3. Just enough discussion of the theory is here given to clarify its application to the present problem. Those who are interested in the theory beyond its present application should refer to the articles mentioned in the foregoing footnote.

$$I_{fA} = \frac{0.57\, E_{LV}}{10}$$

For a fault at B, the current will have to be

$$I_{fB} = \frac{0.57\, E_{HV}}{10}$$

because as the auto-transformer offers no impedance to the flow of zero-sequence currents in its series winding, there will be no stepping-up or down of these currents, and the zero-sequence impedance of the installation will be the same whether measured at A or at B. We thus arrive at the result that

$$\frac{I_{fB}}{I_{fA}} = \frac{E_{HV}}{E_{LV}},$$

the inverse of that for line-to-line short circuits.

If the zero-sequence impedance had been within the generator windings the result could have been in no way different. If the zero-sequence impedance had been partially within the generator and partially within the auto-transformer, the result could again have been in no way different, assuming this time, however, that when the fault is at B the generator is at A, and when the fault is at A the generator is at B. These conclusions were verified by test.

Abridgment of

Starting Performance of Salient-Pole Synchronous Motors

BY T. M. LINVILLE[1]

Associate, A. I. E. E.

***Synopsis.**—This paper presents an analysis of the sub-synchronous speed phenomena of a salient-pole synchronous motor in which formulas and equivalent circuits are developed making it possible to calculate the torque and current for a broad range of conditions. Equations in terms of the impedances of the direct and quadrature axes are first derived from the revolving field point of view. The equivalent circuits for the two axes are then set up and expressions for the separate impedances of the circuit elements established. Adequate means of taking into account the combined effects of salient poles, incomplete amortisseur windings, and open or closed field windings are presented.*

The results obtained are illustrated by a comparison of the predicted performance and test data for a large 60-pole motor. The calculated distribution of current between the amortisseur bars of the same motor is shown by curves. Other curves show the calculated performance of the motor with and without continuous end rings between the poles and with the field winding open and closed. A final example shows the theoretical effects of changing the positions of the bars in the poles of a large waterwheel generator.

* * * * *

Introduction

THE extensive applications of synchronous motors in fields with diverse starting requirements has created a need for accurate methods of predicting their starting characteristics. However, despite the rapid developments in their use, no adequate means for the predetermination of the accelerating torque and current of salient-pole motors has heretofore been published. Many important papers dealing with this general question have been presented, but all have been based on more or less arbitrary assumptions which have seriously limited the generality and usefulness of the methods. None permit accurate determination of the combined effects of pole shape, arbitrarily disposed amortisseur windings, and closed field windings. The methods described in this paper are believed to be adequate for the predetermination of the starting performance of any practical salient-pole synchronous motor.

The method of analysis employed is to derive current and torque equations in terms of the impedances of the direct and quadrature axes of the machine, and then to set up complete equivalent circuits for the armature, field, and amortisseur windings in each axis from which the impedances of the two axes can be calculated. The equivalent circuits are believed to be novel and are quite interesting, since they involve the consideration of the mutual and differential leakage reactances of several dissimilar windings linking parts of a magnetic circuit of non-uniform permeance.

Except for the few assumptions listed in the next section, which are almost universally employed, and which are approximately true for commercial machines, the method is highly dependable. Excellent results have been obtained through its use in practical design calculations and it has afforded a means for studying the effects of the various factors which influence starting performance, in a way not heretofore possible.

Assumptions

1. The armature conductors are effectively sinusoidally distributed in each phase; that is, the mutual inductance of the armature and field circuits is considered a first harmonic only with respect to the elec-

1. D-c. Engineering Dept., General Electric Co., Schenectady, N. Y.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., January 27-31, 1930. Complete copy upon request.

trical space angle. If it is desired to allow correctly for the harmonics due to the armature winding, they can be represented by separate equivalent circuits in series with the fundamental.

2. Saturation and hysteresis are negligible. As saturation exists to some degree in practically all commercial machines, it is necessary therefore to use the results with judgment. Where saturation must be accounted for, judicious shading of the results will allow the method to be used with good accuracy.

Current and Torque Equations

When a salient-pole synchronous motor operates at any subsynchronous speed, the stator currents have two components of different frequencies due to the non-uniform air-gap and to the non-uniformly distributed rotor windings. These two components of current cause the phase currents to be unbalanced at any instant although the average current is identical in every phase. At standstill the two components have the same frequency, but there is unbalance between phases since one component is of negative phase sequence. The average phase currents are not identical under this condition.

The total m. m. f. is composed of components in the direct and quadrature axes pulsating at slip frequency. The current in each axis may be resolved into forward and backward rotating components, each having half the magnitude of the original pulsating m. m. f. These components rotate over the poles at slip frequency.

If I_d is the total current in the direct axis and i_q, the corresponding current in the quadrature axis, it follows that there is a forward current,

$$\dot{i}_f = \frac{1}{2}\,(\dot{i}_d + j\,\dot{i}_q)$$

and a backward current,

$$\dot{i}_b = \frac{1}{2}\,(\dot{i}_d - j\,\dot{i}_q)$$

Since the per-unit velocity of the poles is $(1 - s)$, the forward current moves at a per-unit speed $(1 - s + s)$ or (1) and the backward current rotates at a per-unit speed of $(1 - s - s)$ or $(1 - 2\,s)$. These rotating currents may be solved for by the following treatment.

1. Resolution of the rotating m. m. fs. into stationary pulsating components in each axis of the machine.
2. Determination of the per-unit pulsating air-gap flux components in each axis as the products of the stationary m. m. f. with the impedance of armature reaction in each axis.
3. Resolution of the fluxes into rotating flux waves.
4. Calculation of the voltage produced in the stator by the rotating flux waves.
5. Solution of the stator voltage equations for the currents i_f and i_b, assuming connection to an infinite sine wave bus.

This procedure results in formulas,

$$i_f = \frac{z_d' + x_q'}{(z_d\,z_q' + z_d'\,z_q)}$$

$$i_b = \frac{z_q' - z_d'}{(z_d\,z_q' + z_d'\,z_q)}$$

At half speed these formulas are indeterminate, but here

$$i_f = \frac{2}{z_d + z_q}$$

$$i_b = 0$$

The impedances z_d and z_q are determined by equivalent circuits which are established in the next section.

The expression for torque immediately follows since the average power transferred to the rotor is the real part of the product of the forward voltage (the impressed voltage) and the forward current minus the stator losses. Hence,

$$P_{av} = \bar{e}_f \cdot \bar{i}_f - i_f^2\,r_1 - i_b^2\,r_{1/1-2s}$$

and as per-unit torque is equal to per-unit power, the average torque is,

$$T_{av} = \text{real of } i_f - i_f^2\,r_1 - 1_b^2\,r_{1/1-2s}$$

At any positive speed the phase currents are,

$$i_1 = i_f \cos w\,t + i_b \cos (1 - 20)\,w\,t$$
$$i_2 = i_f \cos (w\,t + 120) + i_b \cos (1 - 2\,s)\,(w\,t - 120)$$
$$i_3 = i_f \cos (w\,t + 240) + i_b \cos (1 - 2\,s)\,(w\,t - 240)$$

where time is measured from the instant when the current vectors i_f and i_b are coincident in phase 1. At 100 per cent slip the current vectors rotate at equal speeds with a constant phase angle between them. Here,

$$i_1 = (i_f + i_b) \cos \theta + j\,(i_f - i_b) \sin \theta$$
$$i_2 = (i_f + i_b) \cos (\theta - 120) + j\,(i_f - i_b) \sin (\theta - 120)$$
$$i_3 = (i_f + i_b) \cos (\theta - 240) + j\,(i_f - i_b) \sin (\theta - 240)$$

where θ is the angle between the axis of phase 1 and the axis of the pole, the pole being ahead of the phase axis.

Equivalent Circuits to Determine the Impedance of Each Axis

The variation in the air-gap, the amortisseur bars, the field circuit, and the pole structure, of a synchronous motor are symmetrical in one axis about the center line of the pole, and in the other about the center line between poles. The stator m. m. f. is also symmetrically distributed about the same center in each axis. Consequently the impedance of either axis may be determined as a transformer problem using an equivalent circuit.

As the amortisseur bars are often of different shape, size, and material, having an unknown current distribution, they cannot be considered together as one circuit but the two bars adjacent to the center line of each axis can be so considered. The next two adjacent bars may be considered as a second circuit, and so forth until all of the bars are accounted for. Thus, instead of a single circuit formed by the amortisseur winding, there is a number of nested circuits, all symmetrical

about the center line in each axis. The determination of rotor impedance then, as a transformer problem, involves a sinusoidally distributed primary winding, an irregular air-gap in the magnetic circuit and a multiple number of dissimilar secondary circuits.

In establishing an equivalent network for either axis of the machine, each circuit is considered separately using an artitrary unit m. m. f. on which to base the calculation of the constants of each. Letting unit m. m. f. exist in any particular circuit the flux is divided into components, that is, the leakage and mutual fluxes are considered separately. The reactance due to each component is determined. Each separate circuit is thus determined in terms of its leakage and mutual reactances. The mutual reactances of the circuits with respect to each other may be replaced by a single reactance so that, by applying this rule, all of the separate circuits join to form the networks shown. The quadrature axis network is exact but a slight approximation is made in the direct axis circuits as discussed in the complete paper. Complete formulas for the separate impedances of the circuit elements will be found in the complete paper. The terms z_d and z_q are the impedances of the direct and quadrature axes respectively. z_d' and z_q' are determined by adding $\left[\frac{r_1}{2s-1} - r_1\right]$ to the impedances z_d and z_q respectively.

Conclusion

With the equivalent circuits and formulas presented it is possible to calculate the complete speed torque characteristic of a motor. It is also possible to determine the induced voltage or current in the field circuit or in any amortisseur bar. The formulas are of great value in studying the effect of various amortisseur designs, pole shapes, etc. In the complete paper it is shown how the method may be extended to cover the case of double squirrel-cage windings. In general, the accuracy of the results obtained is typified by the comparisons of calculated and test curves shown in the illustrations.

It is also possible to predetermine the damping torque to be obtained with any amortisseur design in a generator. For example, curves are given showing the damping torque for six different amortisseur designs in a 77,500-kv-a. waterwheel generator. The lowest curve shows the damping due to the field alone, and the higher curves show the effects of adding amortisseur windings of different spans. Another figure shows the calculated effect of the amortisseur design on the sub-transient reactances. The negative-phase-sequence reactance, which should be as high as possible to limit phase-to-ground and phase-to-phase fault currents decreases as the amortisseur span is increased, and is low when the end rings between the poles are closed. Thus, these calculations make possible a rational decision, taking into account both favorable and unfavorable factors.

Acknowledgment

Special acknowledgment is due to Mr. P. L. Alger, who initiated the study, suggested the equivalent circuit method of analysis, and supervised the work. The author is particularly grateful to him for his work in preparation of the data and in the final writing of the paper. Acknowledgment is also due to Mr. R. H. Park, who developed the complete equations and the mutual relationship of the various windings, and to Mr. Ralph Hammar, who conceived the method of properly caring for the differential leakage reactances of the rotor circuit and who also developed formulas for the circuit constant.

ELECTRIC RAILROAD PROGRESS

Eighteen railroads in the United States, which formerly operated by steam only, now operate electrically on about 4300 miles of track, according to a survey of railroad electrification just completed by the Copper & Brass Research Association.

This electrification represents about 1900 miles of route, and of the 4300 miles of track approximately 3150 miles are main line track. In this electrified territory the railroads have in service 465 electric locomotives and 2750 multiple-unit cars for passenger service. Of these cars 2150 are motor cars and the rest are trailers.

Steam railroad electrifications now in service cover sections of the New England and Middle Atlantic States, the Mid-West, and the West Coast. Among the larger of these electrifications are the Pennsylvania, including the West Jersey and the Long Island, representing 311.5 route miles and 985 miles of track; the Milwaukee, 658.5 route miles and 885.1 miles of track; the New Haven, 171.8 route miles with 712 track miles; New York Central, 63.1 route miles and 328.4 track miles; Virginian, 134 route miles and 231 track miles, and the Norfolk & Western, 63.7 route miles and 209 miles of track.

Electrifications now under construction are Delaware, Lackawanna & Western suburban service at New York involving 73 route miles and 150 total track miles; Illinois Central freight service representing mostly yard track; New York Central freight service on the west side of Manhattan Island; Pennsylvania extension of the Philadelphia suburban service; Reading suburban service at Philadelphia including about 50 miles of route and 110 miles of track, and Grand Trunk (Canadian National) suburban service from Detroit to Pontiac.

It has been definitely announced that the Illinois Central will complete its electrification for all service within the city limits of Chicago and that the Pennsylvania will proceed toward completion of its electrification between New York and Washington.

Definitely authorized projects, says the survey, will within five or six years almost double the present electrified mileage of the steam railroads.

INSTITUTE AND RELATED ACTIVITIES

A. I. E. E. Winter Convention

The opening session of the Winter Convention is under way as this issue of the JOURNAL goes to press. The number of early registrations indicates a large attendance, and the technical and entertainment features announced in the program presage a most profitable and enjoyable week for those in attendance.

A complete report of the convention will appear in the March issue of the JOURNAL.

American Electric Railway Association Convention, June 1930

The 49th Annual Convention of the American Electric Railway Association will be held at San Francisco, California, June 23-26, inclusive, 1930.

The national character of the convention brings together several thousand delegates, comprising railway executives and manufacturers from all parts of the United States, Canada and Mexico. A sizeable delegation from the various European and South American membership of the Association is also expected.

Committees are now at work under the direction of the General Chairman, W. V. Hill, Manager, California Electric Railway Association, with headquarters located at 58 Sutter Street, San Francisco, California. Edwin C. Faber, Vice-President of Barron G. Collier, Inc., New York City, will have charge of the three special trains which are now being arranged for.

Lamme Medal Awarded to R. E. Hellmund

The Lamme Medal of the American Institute of Electrical Engineers has been awarded to R. E. Hellmund, East Pittsburgh, Pa., "for his contributions to the design and development of rotating electrical machinery." It is expected that the Medal will be presented at the Summer Convention of the Institute which is to be held in Toronto, Canada, June 23-27, 1930.

The Lamme Medal was founded as a result of a bequest of the late Benjamin G. Lamme, Chief Engineer of the Westinghouse Electric and Manufacturing Company, who died on July 8, 1924, to provide for the award by the Institute of a gold medal (together with a bronze replica thereof) annually to a member of the A. I. E. E., "who has shown meritorious achievement in the development of electrical apparatus or machinery" and for the award of two such medals in some years if the accumulation from the funds warrants. A committee composed of nine members of the Institute awards the medal.

Mr. Lamme made similar bequests to the Society For The Promotion of Engineering Education and the Ohio State University, providing in the former for the annual award of a medal "for accomplishment in technical teaching or actual advancement of the art of technical training," and in the latter for the award every five years of a medal to a graduate of the Ohio State University in any branch of engineering for meritorious achievement in engineering or the technical arts. The three organizations have adopted a common obverse for their medals and each has prepared a suitable reverse.

The first award of the Lamme Medal of the A. I. E. E. was made in 1928 to Allan B. Field, Consulting Engineer of the Metropolitan-Vickers Electrical Company, Ltd., Manchester, England.

Rudolf Emil Hellmund, Chief Electrical Engineer of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, was born in Gotha, Germany, February 2, 1879. After receiving his early education in Gotha, he attended the Ilmenau Technical College, from which he was graduated with honors in Electrical Engineering in 1898. He later took postgraduate work at the University of Charlottenburg.

Prior to his studies at Charlottenburg, Mr. Hellmund worked for some time as a designer of electrical machinery and spent one year in the laboratory of the "Land-and-See Kabelwerke," Cologne. Subsequently, he was placed in charge of the test floor and laboratory of the "Maschinenfabrik Esslingen," Stuttgart, Germany.

After his course at Charlottenburg, Mr. Hellmund came to the United States and was employed by the Krantz Company of Brooklyn as a designer of switches and switchboards. In 1904 he was employed by William Stanley, of Great Barrington, Massachusetts, with whom he worked on the design of induction motors and also on experimental work on self-compounding alternators. Following this, Mr. Hellmund worked for the

R. E. HELLMUND

Western Electric Company at Hawthorne, Illinois, designing a line of induction motors which was then marketed by that company. In 1907 Mr. Hellmund entered the employ of the Westinghouse Electric and Manufacturing Company as a designer of induction motors. Later he was engaged in general engineering work and, in 1912, was placed in charge of the design of all direct and a-c. railway machines.

In 1917, Mr. Hellmund was assigned miscellaneous consulting work, in which he continued until 1921, when he was appointed engineering supervisor of development. In 1926 he was appointed chief electrical engineer of the company.

In his engineering experience with the Westinghouse Company, Mr. Hellmund developed new ventilating systems and stator structures of various types of machines, numerous control systems, new armature windings, regenerative systems for railways, control systems and structures for phase-converters and phase-converter locomotives, all of which are in practical use. He obtained in the neighborhood of three hundred United States

and foreign patents covering various features of the above mentioned and similar subjects.

Mr. Hellmund is the author of many papers which have appeared in the TRANSACTIONS of the American Institute of Electrical Engineers, and *Proceedings* of the British Institution, and various other American and foreign technical magazines; covering such subjects as rotating fields and leakage fluxes in a-c. machines, single-phase commutator motors, regenerative control for railways, electric traction, engineering education, etc.

He joined the Institute in 1905, was transferred to the grade of Member in 1909, and became a Fellow in 1913. He is also a member of the German Electrotechnical Society.

A Course in A-C. Bridge Measurements

As previously announced in the Institute's JOURNAL, (October 1929, p. 781) Doctor Bernard Hague, D. Sc., Ph. D., M. I. E. E. Senior Lecturer in Electrical Engineering at the University of Glasgow, Scotland, and visiting Professor at the Brooklyn Polytechnic Institute will conduct a course of 15 lectures thereon the recent developments in the theory and practise of a-c. bridge measurements. The first lecture will be delivered the evening of Tuesday, February 11th, from 7 to 9 p. m., with one each consecutive Tuesday evening thereafter at the same hour.

They will be of a postgraduate nature, open to college graduates and persons interested in and qualified for advanced theory and practise of a-c. measurements. The lectures will comprise a systematic study of the subject, supplemented by suggested courses of reading. It is hoped that by the time the course starts, the revised edition of the book on "Alternating Current Bridge Measurements" by Doctor Hague, will be available for those who wish a copy.

The course will consider the general topics of the general theory of bridge networks, circuit transformations, mutual inductance in bridges, estimation of network sensitivity; a-c. bridge apparatus, standards of resistance, self and mutual inductance, capacitance, sources, detectors, auxiliaries, and the theory of vibration galvanometers; the classification of a-c. bridge networks and their general characteristics, discussion of the quantities measurable by bridge methods, practical limitations; typical bridges for various classes of measurements, theory, practical use, sources of error and sensitivity of the methods described; and, precautions necessary in the use of bridge networks, theory of earth admittances, shielding and earthing devices.

Every applicant is requested to submit appropriate form obtainable at the Office of the Dean, with an official transcript of college record, readily obtainable from the Dean or Registrar of his college. If at some later period applicants become matriculated graduate students, credit for passing this course may be applied toward a Master of Electrical Engineering degree.

The fee for the course is $30.

Presentation of the John Fritz Medal for 1930 to Ralph Modjeski

The John Fritz Medal was presented to Dr. Ralph Modjeski of New York and Chicago, Member, American Society of Civil Engineers, at the annual banquet and reception of the Society in the Hotel Commodore, New York City, Wednesday evening, January 15, 1930. Approximately 600 members and guests of the Society with their ladies were present. Immediately following the dinner Mr. Harrison P. Eddy, Member of the Society, as Master of Ceremonies, presented the newly elected President of the Society and three Honorary Members, and then resigned the Chair to Bancroft Gherardi, Past-President, of the Institute as Chairman of The John Fritz Medal Board of Award.

Mr. Gherardi spoke briefly of the purposes and history of the medal and introduced Mr. J. V. W. Reynders, Past-Chairman of the Board of Award, and Past-President of the American Institute of Mining and Metallurgical Engineers. Mr. Reynders most interestingly summarized the achievements of the 25 preceding medalists, in subject groups, and then entertainingly outlined Dr. Modjeski's personal history emphasizing his contribution to the art of bridge building, especially during the period of construction of great bridges in the United States.

Chairman Gherardi then presented Dexter S. Kimball, Past-President of the Mechanical Engineers, as Chairman of the Board which made the award to Doctor Modjeski, to express his thought on the social effects of engineering. Doctor Kimball spoke most inspiringly, particularly of the great contributions to human life made by engineers and scientists in the fields of machine tools, application of power, transportation and communication. He also alluded briefly to great contributions of the sanitary engineer and of the medical research men for the benefit of public health and of the engineering educator to the general advancement of the practise of the profession.

Following his address and in accordance with established custom, Dr. Kimball, as Chairman of the Board when this award was made, presented the medal and certificate to Dr. Modjeski for "notable achievement as an engineer of great bridges combining the principles of strength and beauty." Doctor Modjeski responded very briefly accepting the honor.

The charming setting of the mixed company of ladies and gentlemen with pleasant friendly atmosphere, and the excellence of the addresses coupled with the dignity and fitness of Mr. Eddy's discharge of his duties as Master of Ceremonies, made this one of the most pleasing and impressive presentations of the medal.

AMERICAN ENGINEERING COUNCIL

NEW COUNCIL PRESIDENT

At the Annual Meeting of American Engineering Council held at the Mayflower Hotel, Washington, D. C., January 10, Mr. Carl E. Grunsky was elected President for the two years, 1930 and 1931.

In 1878 he found his first employment under the State Engineer of California as topographer with a field party. He was in the State Engineer Department for ten years, having been advanced to the positions of Assistant and Chief Assistant State Engineer.

During this period he was engineer for a number of irrigation districts, notably Modesto, Central (now Glenn Colusa), Colusa, College City, Orland, South Side, and Kraft, some of which however, did not proceed beyond the making of plans and cost estimates. He was also consulting engineer on water works and sewerage projects and was made a member of a Sewerage Board for San Francisco, which, although of short life, laid the foundation for the system of sewers and intercepting sewers of whose design Mr. Grunsky had charge in 1899. For four years thereafter, under a new charter adopted at that time by San Francisco, he was City Engineer of that city.

From the position of City Engineer of San Francisco, he was called to Washington by President Roosevelt to become of one the four engineer members of the Panama Canal Commission.

Upon reorganization of the Canal Commission in 1905, Mr. Grunsky was appointed Consulting Engineer in the U. S. Reclamation Service and Advisor to the Secretary of the Interior on reclamation problems.

He has always taken an active interest in furthering and assisting technical and scientific organizations, as one of the founders and with uninterrupted membership in the Technical Society of the Pacific Coast; Pacific Association of Consulting Engineers; the Engineers Club of San Francisco. He is a life member of the California Academy of Sciences, of which he has

been president for 17 years; he is also life member of the Sacramento Museum Association; Commonwealth Club of California (Past-President); and of the American Society of Civil Engineers, of which he was president in 1924. He is a member of the American Association for the Advancement of Sciences, and held the presidency of the Pacific Division of that Association in 1925.

Besides the degree of Dr. Ing. obtained from the Polytechnic Institute at Stuttgart, he also holds the degree of Eng. D. from the Rensselaer Polytechnic Institute.

ANNUAL MEETING

The annual meeting of American Engineering Council convened in the Mayflower Hotel, Washington, D. C., January 10, 1930. This meeting was preceded by meetings of the outgoing Executive Committee and Administrative Board on January 9. Several other important committees met upon this date also.

Sixty delegates coming from all parts of the United States and representing 24 engineering societies having a constituent membership of 58,000 professional engineers, attended the annual meeting. Outgoing President, A. W. Berresford, delivered an address which was followed by Reports of the Executive Secretary, Treasurer, and Auditor.

The officers elected for the coming year were as follows: Carl E. Grunsky, President; L. B. Stillwell, G. S. Williams, L. P. Alford and O. H. Koch, Vice Presidents; Dr. H. E. Howe, Treasurer.

The Administrative Board for 1930 is composed as follows: C. O. Bickelhaupt, H. A. Kidder, R. F. Schuchardt, C. F. Scott, C. E. Skinner, (American Institute of Electrical Engineers) H. S. Crocker, A. J. Dyer, Anson Marston, Frank M. Williams (American Society of Civil Engineers); Chas. Piez, John Lyle Harrington, R. C. Marshall, Jr., E. N. Trump, John H. Lawrence, D. Robert Yarnall (American Society of Mechanical Engineers); Dr. H. E. Howe (American Institute of Chemical Engineers); Edwin F. Wendt (American Institute of Consulting Engineers); Prof. William Boss (American Society of Agricultural Engineers); *Regional Districts* (No. 1) George A. Reed; (No. 2) B. A. Parks; (No. 3) J. S. Dodds; (No. 4) C. B. Hawley; (No. 5) A. A. Krieger; (No. 6) W. W. Horner.

The Public Affairs Committee is usually one of the most active of all the committees of Council; D. Robert Yarnall of Philadelphia, Chairman. Some of its outstanding recommendations were that Council reiterate its endorsement of the development of commercial aviation but on the ground that it does not accomplish in a practicable manner that it oppose Senate Bill 2214 dealing with this subject.

In reporting upon the Cramton bill (H. R. 26), the committee favored the support of the development of the national city parks in such manner as to include all major elements of city planning. Recommending, however, that the bill be amended to permit the development of hydroelectric power at Great Falls by private enterprise. It's belief was that proper hydroelectric development as well as flood control and navigation should all be carried out in harmony with proper city and park planning.

In consideration of H. R. 5575, dealing with beach and shore erosion, it was recommended by the Public Affairs Committee, and adopted that this bill be opposed on the basic ground that the work was not of value to the general public but rather to local coastal interests.

In response to a request from Congressman Mapes for a suggested amendment to H. R. 733, providing for a deep waterway from the Great Lakes to the Atlantic Ocean by way of the St. Lawrence River and the Welland Canal, Council voted to recommend the following amendment:

"The engineers who shall represent the United States on said board shall be appointed by the President of the United States, and at least one-half of them shall be civilian engineers experienced in transportation and commercial practise and not in the employ of the Federal Government; the other members shall be engineers equally qualified in Federal engineering practise."

Council endorsed President Hoover's recommendation concerning Muscle Shoals in principle and re-affirmed its opposition to all Muscle Shoal bills that contemplate government ownership or operation or those bills which set aside the intent and purpose of the Federal Water Power Act.

In consideration of H. R. 1410, for aiding farmers on wet lands in any state by the making of loans to drainage districts, levee districts, counties, boards of supervisors, political subdivisions, local entities, etc., the Council recorded its judgment as being not in sympathy with this bill.

In consideration of H. R. 7879 by Congressman Denison, Council voted the appointment of a special committee to consider all bridge bills.

Considerable discussion was given by delegates of Council to H. R. 7578, H. R. 5616, H. R. 7586 and H. R. 7585, all of which provide for additional appropriations for Federal aid to state highway construction. No action was taken upon these bills because it was felt that they dealt primarily with the question of financial policy of the U. S. Government and not strictly with engineering. Stabilization of Wages to aid Industry, H. J. Res. 162, Mr. Sabath, was opposed by Council on the ground of impracticability.

A bill, H. R. 5694 by Mr. Clarke of New York, providing for additional appropriations for reforestation, was favorably considered as was the bill by Mr. McNary, S. 2246.

Council however, voted to oppose the McNary bill, S. 2366, which provides for an increase of the proportion of the annual receipts from national forests to be paid to the states for the benefit of public schools and public roads, on the ground that the percentage provided was exorbitant.

Council recommended the support of the Shipstead-Nolan bills, S. 2498 and H. R. 6981 which "promote the better protection and highest public use of lands of the United States and adjacent lands and waters in Northern Minnesota for the production of forest products and other purposes."

Council recommended the following amendments to this bill:

(1) Those amendments offered in Senate Report No. 1782, 70th Congress, 2nd Session, by the Committee on Agriculture and Forestry effect offer many prohibitions which provide that restriction shall not apply to proposed development for water power purposes for which application for license was pending before January 1, 1928; and provide that the Secretary of Agriculture may open for homestead entry such included lands as may be found by him to be chiefly valuable for agricultural purposes.

(2) Amendments which shall provide that: (a) The included area shall be so limited as not to take in scattered federal lands in the farming and mining communities which are already established and that (b) Local development of small scale hydroelectric power on private lands and for private purposes shall not be restricted (c) That an amendment shall provide for right of ways for railways and highways necessary to the development of mineral resources as well as the economic utilization of forest products.

Detail of Engineers to Latin-American Republics: The Oddie Bill, S. 120, was again vigorously opposed because it disguised the fact that the United States proposed to present money to these South American countries for the construction of roads, and because it permits Government employees to receive two salaries simultaneously, one paid by the Government of the South American countries and one of the United States, and finally, because the bill does not limit the time that an engineer from the Bureau of Public Roads may serve a foreign country.

The representatives of the American Institute of Electrical Engineers in attendance were: Messrs. A. W. Berresford, C. O. Bickelhaupt, F. J. Chesterman, N. M. Fowler, F. L. Hutchinson, W. S. Lee, L. F. Morehouse, I. E. Moultrop, Farley Osgood, R. F. Schuchardt, Chas. F. Scott, Harold B. Smith and L. B. Stillwell.

UNIFIED OPERATION OF COMMUNICATION SYSTEMS APPROVED

The bill of Senator Couzens which provides for the organization of a new federal regulatory commission to be called Federal Commission on Communications and Power is opposed in a progress report of the Committee on Communications of the American Engineering Council. Unified operation of communications systems, wire and wireless, under Government regulation is favored.

The Council's Committee, headed by Edwin F. Wendt of Washington, D. C., is making an exhaustive study of the proposed legislation, which is also being investigated by many other national bodies of professional and business men, including the American Bar Association and the United States Chamber of Commerce.

The Committee reports in part as follows: "The regulation of telephone, telegraph, and cable common carriers should remain with the Interstate Commerce Commission as now provided by law.

The American Engineering Council should favor congressional legislation which will permit the unified operation of telephones, telegraphs, cables, and radio, under governmental regulation. This plan is sound from an engineering and economic standpoint, and should result in improved service in both national and international communications."

The members of the Committee include O. H. Caldwell of New York, former member of the Federal Radio Commission; A. J. Hammond of Chicago, Dean Dexter S. Kimball of Cornell University, C. B. Hawley of Washington, and Frank A. Scott of Cleveland. The recommendations of the Committee are under consideration by the Administrative Board of the Council.

STANDARDS

Graphical Symbols for Electric Power and Interior Wiring

A report on a proposed American Standard for Graphical Symbols for Electric Power and Interior Wiring developed by a subcommittee of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations was received at the December 13, 1929 meeting of the A. I. E. E. Standards Committee and was ordered printed in report form for distribution for purposes of criticism and suggestion. This report comprises graphical symbols used for one-line and complete diagrams of electric power apparatus, instruments and relays, system-connection diagrams, and interior wiring diagrams. The symbols are limited to apparatus usually met with in electrical power engineering, such as major electrical equipment in power houses, substations, and transmission and distribution systems and to system and building wiring diagrams. They are not intended to cover communication, railway or other allied branches of electrical engineering. Basic symbols seem to have widespread use and application, and only such symbols are given. This report will shortly be available in pamphlet form and copies may be had without charge by writing H. E. Farrer, Secretary, A. I. E. E. Standards Committee, 33 West 39th Street, New York, N. Y.

Work on American Standards for Electrical Definitions Progressing

The Sectional Committee on Electrical Definitions under the chairmanship of Dr. A. E. Kennelly of Harvard has about completed the necessary steps in organization. Fourteen subcommittees have been decided upon and chairmen selected and the scope of each determined. The personnel of these subcommittees is now being selected by the chairmen. As soon as this work is complete the actual coordination of existing definitions will begin. In making up the subcommittees an effort is being made to keep them as small as possible with the understanding that whenever necessary non-member experts may be called in to help. The next meeting of the Executive Committee has been set for March 5, 1930.

Commercial Standards Monthly

The Bureau of Standards has just announced the establishment of a new monthly publication "The Commercial Standards Monthly." Dr. Burgess, Director of the Bureau of Standards in describing the new bureau publication said that the monthly will give its readers a more comprehensive account of progress made in standardization and simplification, and it is hoped, a clear vision of just what the functions of the Bureau of Standards means to the American public. Subscriptions should be entered with the Superintendent of Documents, Government Printing Office, Washington, D. C. Subscription price $1.00 per year (domestic), $1.25 (foreign).

Standards of the I. E. C.

The work of the International Electrotechnical Commission, over the past twenty years, has resulted in a considerable body of international electrical standards, which have been published from time to time in the form of individual reports. These standards are intended primarily for use in international trade.

For the convenience of any who may wish to obtain these standards the United States National Committee, 33 West 39th St., New York, N. Y., will be glad to provide them at the prices indicated in the following list. In order to obviate the necessity of carrying small items in the Committee's accounts, and to elimination of bookkeeping, payment in advance is requested. We believe it desirable that, in any publicity you may decide to give these standards, this latter point should be mentioned.

They may be obtained direct from the Central Office, International Electrotechnical Commission, 28 Victoria Street, Westminster, London S. W. 1, England.

No.	Date	Title and scope	Price
27	December 1920	**International Symbols (First Part) Letter Symbols.** (Letter symbols for fundamental, physical, and electrical quantities. Names and abbreviations of electrical units. Mathematical letter symbols)	$0.50
28	March 1925	**International Standard of Resistance for Copper.** (Specification for standard resistance of copper, including standard annealed copper, commercial copper, and temperature coefficients)	0.50
34	March 1920	**I. E. C. Rules for Electrical Machinery** (Now in process of revision). (Rules for rating of electrical machinery, limits of temperature and temperature rise for rotating machinery and transformers of small or moderate capacity, terminal markings, and information to be given with inquiries and orders for electrical machines	0.55
35	1927	**International Symbols (Part 2) Graphical Symbols for Heavy Current Systems.** (Graphical symbols for supply systems, including circuits, transformers, rotating machines, measuring instruments, and traction systems and apparatus	1.10
37	1927	**Standard Dimensions of Bayonet Lamp Sockets and Caps.** (Standard dimensions of bayonet lamp sockets and caps	0.25
38	1927	**I. E. C. Standard Voltages.** (Standard voltages, tables of preferred average voltages of transmission and distribution lines at consumer's terminals)	0.25
39	1927	**International Rules for Traction Motors.** (Rules for the rating of traction motors. The temperature rating of motors for traction purposes, including continuous rating and one-hour rating)	0.25
41	1928	**I. E. C. Publication on the Testing of Hydraulic Turbines.** (Testing of hydraulic turbines. Methods and conditions of tests, and the efficiency of hydraulic turbines)	0.50

American Standards Association

Announcement has just been made by William J. Serrill, president of the A. S. A. that the underwriting of the finances of the A. S. A. for a period of three years to permit a total annual expenditure of $150,000 for the Association's work is now being completed. This fund permits an increase in the 1930 budget of $80,000 over the previous budget of the association and is expected to result in an expansion of national standardization work affecting practically all industries.

The fund is being underwritten by a large group of industrial organizations. The underwriting was arranged by a committee consisting of James A. Farrell, President of the United States Steel Corporation; Gerard Swope, President of the General Electric Company; George B. Cortelyou, President of the Consolidated Gas Company of New York; and F. A. Merrick, President of the Westinghouse Electric and Manufacturing Company.

Because of the rapid growth of the industrial standardization movement in this country, the underwriting was planned to permit immediate expansion of the work of providing authoritative national standards while permanent financing is under way. It is expected that this financing will be completed during the three year period of the underwriting.

Among the companies joining in the underwriting are: Aluminum Company of America, American Telephone & Telegraph Company, Bethlehem Steel Company, Consolidated Gas Company of New York, Detroit Edison Company, General Electric Company, General Motors Corporation, Gulf Oil Corporation of Pennsylvania, Public Service Corporation of New Jersey, Standard Oil Company of New Jersey, U. S. Steel Corporation, Westinghouse Electric & Manufacturing Company and Youngstown Sheet and Tube Company.

Up to the present time the Association has adopted approximately 160 national standards, and 190 other national standards are being formulated. The Association provides the machinery by which all of the producing, distributing, and consuming groups concerned with a standard may cooperate in its preparation. The foremost technicians of all groups are thus brought together to pool their knowledge for the benefit of all. Over 2000 individuals representing 800 cooperating organizations are in this way working on technical committees under the procedure of the Association.

An important feature of the Association's work is the adoption of national standard safety codes, which are used voluntarily by industries and also as the basis for state and municipal safety regulations and for the regulations of insurance companies in numerous states. Among the most important of these codes are the National Electrical Safety Code, the Code for Mechanical Power Transmission, and several codes for mine safety.

As the result of the recent affiliation of the American Home Economics Association with the American Standards Association, this latter body has begun also important standardization work on projects of direct concern to the ultimate consumer, such as refrigerators, sheets, and blankets.

ENGINEERING FOUNDATION

ITS ORGANIZATION AND FUNCTIONS

Engineering Foundation, Inc., successor to United Engineering Society by change of name only, is a non-profit, membership corporation whose charter gives it broad powers for the advancement of the engineering arts and sciences. It was set up by four national societies,—the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, which therefore came to be known as the Founder Societies.

Objections had been voiced from time to time to the name "United Engineering Society" and experience for many years had demonstrated that this name caused confusion, misconceptions and other difficulties. The organization is not a "society" in the usual conception of the word. It is a corporation administering through the engineering profession and the related sciences and industries real estate, funds, and a library, for scientific, educational and other purposes beneficial to the public. Its functions correspond closely to those of corporations of universities and of foundations for scientific, social, or economic research. It is truly a "foundation;" the name "Engineering Foundation" is appropriate. Therefore, with the approval of the Founder Societies its name was changed beginning January first, 1930.

The corporate powers and privileges of the Foundation are vested in and exercised by a Board of twelve Trustees, three from each Founder Society, to which all departments are responsible. The Foundation has three departments:

Engineering Societies Research Board, Engineering Societies Library Board, and Administrative Department.

It is titular owner of Engineering Societies Building, and the trust funds for the Library and Research Board. The Foundation and its departments are tax exempt.

Engineering Societies Research Board was established in 1914 by the Founder Societies "for the furtherance of research in science and in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." It was conceived by Ambrose Swasey, of Cleveland, Ohio, and toward its endowment he has made three gifts intended to be the nucleus of a great "community trust" for engineers, to be contributed by many donors.

The Research Board has sixteen members; three representatives of each Founder Society, three members-at-large chosen by the Board of Trustees, and the President of the Foundation, *ex-officio*. It has discretionary power in disposition of income from the Engineering Foundation Fund and other sources, but responsibility for administration of principal lies with the Board of Trustees.

Engineering Societies Research Board enjoys the cooperation of engineering societies, National Research Council, technical bureaus of the Government, universities, scientific associations, industries, bankers, and individual engineers. Funds contributed by others to projects in which it has participated have aggregated hundreds of thousands of dollars, and the services, facilities, and materials given in addition probably a much larger total. In the 15 years of its existence, it has aided in establishing National Research Council, and has cooperated in organizing the Highway Research Board, The Bureau of Welding and the Personnel Research Federation. It made possible the Fatigue of Metals Research at University of Illinois; assisted the Marine Piling Investigation, is aiding its Founder Societies financially and otherwise in numerous researches, some of the larger projects being an investigation of arch dams for power development, irrigation, water supply and flood control; researches in properties of steam, alloys of iron, and wire ropes.

Engineering Societies Library is a free public library. It contains 125,000 books and pamphlets and 6000 maps. It receives regularly, from all over the world, 1700 technical periodicals in 18 languages: Chinese, Czech, Danish, Dutch, English, French, German, Hungarian, Icelandic, Italian, Japanese, Norwegian, Polish, Portuguese, Roumanian, Russian, Spanish and Swedish. A board of twenty-one members manages the Library,—four designated by each Founder Society, the Secretary of each Society, and the Director of the Library.

The Library maintains staffs of technically trained searchers and translators, as well as reference assistants. It makes photoprints of any material in its collection. A card service keeps subscribers informed of articles in periodicals on subjects in which they may be interested. It has special arrangements for lending books. By these means the Library serves thousands, near and far. For some services moderate charges are necessary. It has

users in every state and territory of our country and in many foreign countries. It is supplemented by the Engineering Index Service of The American Society of Mechanical Engineers.

The Administrative Department manages Engineering Societies Building and all trust funds. This building, headquarters for more than a score of engineering organizations, almost all national in scope, is situated in the midst of New York's newly developed mid-Manhattan business, hotel, theater and club district, equidistant from the two great railroad passenger terminals. In the building, besides quarters of societies, there is the Entrance Hall, or lounge; the Engineering Auditorium, seating 900; three assembly rooms, seating 90, 225, and 500; committee rooms, and Engineering Societies Library. The Founder Societies have equal interests in the ownership, occupancy and administration of the building. The Society of Automotive Engineers also occupies an entire floor. These five large societies use nearly the whole space of the eight office floors. The building houses also Engineering Foundation, Inc., Engineering Societies Employment Service, American Standards Association, Division of Engineering and Industrial Research of National Research Council, and Personnel Research Federation.

The funds administered are: Engineering Foundation Fund, Library Endowment Fund, Henry R. Towne Engineering Fund, Edward Dean Adams Fund, John Fritz Medal Fund, and Depreciation and Renewal Fund (for Engineering Societies Building).

Engineering Foundation, Inc., has power to establish other departments, with the approval of its Founder Societies, and to accept additional funds.

Minutes of International Conference on Large Electric High-Tension Systems

The fifth session of the International Conference on Large Electric High-Tension Systems was held in Paris in June 1929. The object of the Conference, which meets every two years, is to investigate all questions relating to production, transmission and distribution of electricity at high tension. The United States is one of the thirty-two countries sending delegates to these conferences. The reports issued at the close of each session constitute a survey of progress for the preceding two year period. The reports of the June 1929 session will be available in March 1930. They will be issued in three volumes of 800 pages each. The price will be 325 francs for paper covered editions and 355 francs for cloth bound. Subscriptions should be sent to Secretariat, Conference Internationale, Boulevard Malesherbes 25, Paris, France.

A New Award for Service

The American Association of Engineers in the future will endeavor to award each year the Claussen Gold Medal to the citizen of the United States (engineer or otherwise) who has during the preceding year performed the most distinctive service for the welfare of engineers—social or economic, or both. It is not to be awarded for engineering or scientific achievements unless they have served very definitely and directly to promote the social and economic welfare of engineers. The first award will be made for services rendered prior to Jan. 1st, 1930. The medal was designed by Elwyn Giles, and Amos Mazzolini is the sculptor. The personnel of the Committee that will make the award is as follows:

G. M. Butler, Dean College of Mines and Engineering, University of Arizona, Chairman. L. W. Baldwin, President Missouri Pacific Lines, St. Louis, Missouri. C. F. Kettering, General Director Research Laboratories, General Motors Corporation, Detroit, Michigan. R. B. von KleinSmid, President University of Southern California, Los Angeles, California. Arthur E. Morgan, President Antioch College, Yellow Springs, Ohio. Michael J. Pupin, Physicist, Columbia University, New York City. W. J. Saunders, Chairman of the Board, Ingersoll-Rand Company, 11 Broadway, New York City. A. N. Talbot, College of Engineering, University of Illinois, Urbana, Ill. J. W. Thomas, Vice President Firestone Tire and Rubber Co., Akron, Ohio. Geo. C. Warren, Chairman Executive Committee, Warren Brothers Co., Boston, Mass.

Among the achievements to merit the award are; publication of articles that impress the public with the value and importance of the work of the engineer; the successful promotion of laws that may improve the economic and social status of engineers; public service of such a nature as may bring engineers and engineering prominently to the attention of the people; the successful direction of an organization devoted to the promotion of the welfare of engineers; the creation of a nationwide employment service for engineers or of a feasible plan for unemployment insurance, and the creation of a foundation to investigate the employment situation that now confronts engineers. This list is merely suggestive and there are doubtless other activities worthy of attention.

The committee invites nominations of persons to receive this medal. These nominations should be sent to the Chairman of the committee and should include fairly complete bibliographies of nominees as well as a full statement of the services rendered which would seem to make them eligible for the award.

While nominations made by individuals will be carefully considered, those offered by national, regional, state, or local groups will naturally carry more weight with the committee and are particularly invited. The first award of the medal will probably be made late next spring.

Research Fellowships at Michigan College of Mining and Technology

The Michigan College of Mining and Technology is offering for the academic year of 1930-1931 twelve graduate fellowships carrying stipends of $1200 each. Holders of these fellowships will be engaged in the study of various problems in connection with the general research program of the college for which the State of Michigan has provided the sum of $50,000 for the coming year. This program deals with the iron and copper resources of Northern Michigan and with their utilization.

Each fellowship will carry full exemption from all fees except the regular matriculation fee and the diploma fee. The fellowships are open to college graduates who have a Bachelor of Science degree or its equivalent and who are qualified to undertake research in chemistry, geology, geophysics, electrical engineering, mechanical engineering, metallurgy, mining or ore dressing.

Fellows in chemistry, geology, electrical and mechanical engineering and mining will be appointed for the year Oct. 1, 1930 to Oct. 1, 1931, with a vacation of one month to be taken in September; fellows in physics, geophysics, metallurgy, and ore dressing will be appointed for the year July 1, 1930 to July 1, 1931, with a vacation of one month.

Fellows will register as graduate students at the Michigan College of Mining and Technology and will become candidates for the degree of Master of Science. A fellow may be required to devote a portion of his time to instruction, not to exceed six hours per week in the class-room or ten hours per week in the laboratory. The normal time for the completion of the work required for the advanced degree will be one year.

Applications containing a certified copy of college record, a statement of experience, and the names and addresses of at least three references must be in the hands of L. F. Duggan, Registrar, Michigan College of Mining and Technology, Houghton, Michigan, not later than May 15, 1930. Appointments will be made by June 15, 1930.

Engineering Lectures at Swarthmore

The William J. Cooper Foundation of Swarthmore College announces a series of lectures in the field of engineering to be given during February and March, 1930. The subjects and speakers are as follows:

Friday, February 14th, "Large Bridge Structures and Recent Advances in Construction," Dr. Ralph Modjeski, Consulting Civil Engineer.

Thursday, February 20th, "Electrical Communication," Dr. Frank B. Jewett, Vice-President American Telephone and Telegraph Co.

Thursday, February 27th, "Transportation—An Evolution," Mr. Elisha Lee, Vice-President of the Pennsylvania Railroad.

Friday, March 7th, "The Science of Management," Mr. Henry S. Dennison, President of the Dennison Manufacturing Co.

All the lectures will be given at the Meeting House, Swarthmore College, at 8:15 p. m. Cards of admission may be secured from the Committee on the Wm. J. Cooper Foundation, Swarthmore College, Swarthmore, Pennsylvania. For single lectures such cards as are available will be obtainable at the College Book Store on and after the Tuesday preceding the event.

PERSONAL MENTION

H. Hobart Porter, Trustee of Columbia University, will sail on the Steamship *Columbus*, January 21, for a cruise around the world. Mr. Porter is President of the American Water Works and Electric Company, and chairman of the Engineering Foundation.

Robert L. Allen, who, for many years was connected with the Archbold-Brady Company of Syracuse, N. Y., as Chief Engineer has become associated with the Lackawanna Steel Construction Corporation of Buffalo, as Manager of the Department handling the design and fabrication of transmission towers and other structures for electrical work.

E. B. Meyer, member of the Institute's Board of Directors and Chairman of the Finance Committee, has just been elected Vice-President of the Public Service Production Company Division of United Engineers & Construction, Inc., Newark, New Jersey, with whom he has been associated ever since 1903. Mr. Meyer has served on many of the Institute's committees and has also been active with the National Electric Light Association, The American Society of Mechanical Engineers, the Essex Electrical League, the New York Electrical Society and the American Electric Railway Association.

Edward H. Hubert, formerly a member of the headquarters staff of the American Institute of Electrical Engineers, has been appointed director of publicity for the National Electrical Manufacturers Association to succeed Albert Pfaltz, resigned.

At Institute headquarters where Mr. Hubert has been located during the last six years, he has been secretary of the Meetings and Papers Committee with work in connection with the arrangement of convention programs and with publications. He was formerly with the McGraw-Hill Publishing Company where he served in the editorial department of *Electrical World* and other publications. He was also previously connected with the Engineering Department of the Georgia Power Company.

Obituary

Frederic Cutts, Manager of the United Illuminating Company, Bridgeport, Connecticut, died January 11, 1930, as the result of an infected throat. He came to the United Illuminating Company after fifteen successful years of service with the General Electric Company at New Haven, Conn. A native of New Rochelle, N. Y., his general education was Wesleyan University (B. A.); technical, Cornell University (E. E. in M. E.); and special, General Electric Student Course. He was Engineer in charge of Design Installation of underground distribution systems of the Syracuse Lighting Company in 1899; District Engineer of the General Electric Company, Atlanta, Ga. from 1900 to 1905; Assistant to the Chief Engineer of Ford, Bacon & Davis, New York for one year, doing report and office management work, after which he was sent by them to take over the complete direction of working forces in Nashville, Knoxville, Memphis, Birmingham, Little Rock and Houston, these operations averaging from 4000 to 5000 men. In 1909 he became Resident Agent for the General Electric Company, at Providence, R. I., and in 1913 took up his work as Local Manager of the company's New Haven office. Mr. Cutts joined the Institute in 1919 as a Member.

Ralph Willis Goddard, Dean of the Engineering School of the New Mexico College of Agriculture and Mechanical Art was killed New Year's Eve while at work on the College Broadcasting Station. He was born at Waltham, Mass., April 20, 1887, and obtained his high school education at English High School, Worcester, Mass., in 1911 he was graduated from Worcester Polytechnic Institute with the degree of B. S. in E. E., and received his Professional degree from Worcester Polytechnic Institute in 1929. For a few years he was engaged in electrical contracting and building but gave up commercial work to join the engineering faculty of the University of Nebraska in 1913. In 1914 he went to New Mexico College of Agriculture and Mechanic Arts as professor of Electrical Engineering, and in 1920 he was made Dean of the School of Engineering. At the time of his death he was professor of Electrical Engineering, Dean of Engineering, director of the Engineering Experiment Station and Director of KOB. He was also a member of the radio committee of the Land Grant College Association; Secretary of the Association of College and University Broadcasting Stations and a member of the American Association of Engineers, the Institute of Radio Engineers, the American Association for Advancement of Science, the National Electric Light Association, the Society for Promotion of Engineering Education, the New Mexico Utilities Association, and the New Mexico Educational Association. He is credited with a number of inventions, including the motorcycle side car. He had made to his own special design, in the College shops and laboratories, practically the entire broadcasting equipment for radio station KOB, the most powerful educational station and one of the 13 most powerful broadcasting stations in the world.

Sebastian Ziani de Ferranti, one of the pioneers in the field of electric power distribution and an Honorary Member of the Institute since 1912, died at Zurich, Switzerland, January 13, 1930, at the age of 65.

He was born at Liverpool, England, and was educated at Hempstead School, St. Augustine's College, Ramsgate, and University College, London. At quite a youthful age he displayed unusual capacity for machine design; in fact when he was between ten and twelve years old he had produced original drawings demonstrating his extraordinary grasp of details. His work in engineering and science is well known throughout the civilized world; an honorary luncheon tendered him in 1924, at the Yale Club, New York, by the officers of the American national societies of civil, mining, mechanical, and electrical engineers "afforded opportunity for recognition by American engineers of the presence in the United States of one of the most eminent engineers of Great Britain." When 22 he began his work of supplying London with electricity from a plant remote from the city, and in 1891 the scheme was perfected and regular voltage of 10,000 was transmitted to the city. The large Ferranti power plant at Hollinwood was started in 1895. Of recent years, Doctor Ferranti had been deeply interested in radio developments and devoted exhaustive study to the audio frequency transformers, which he brought to a high degree of perfection. His contributions to the profession have been marked

in connection with the electric furnace, the electric-energy meter, the improvement of alternating-current generators and motors, and, as above stated, in his remarkable pioneer work in high-tension alternating current generation and distribution. Installations made by him embraced notable ideas, and his undertakings, carried through to successful completion against the heavy odds of many difficulties, remain a monument of his accomplishment through ability and application.

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York.

All members are urged to notify Institute Headquarters promptly of any changes in mailing or business address, thus relieving the member of needless annoyance and assuring the prompt delivery of Institute mail, through the accuracy of our mailing records and the elimination of unnecessary expense for postage and clerical work.

Baer, C. A., 1330 Pine St., Philadelphia, Pa.
Bakker, J. B., 440 Hyde St., San Francisco, Calif.
Bell, C. W., P. O. Box 424, Port Chester, N. Y.
Birdsall, W. T., 6 Vincent Place, Montclair, N. J.
Brown, Garry E., 1280 Dean St., Brooklyn, N. Y.
Chin, Lung C., 200 Claremont Ave., Apt. 57, New York, N. Y.
Collinot, Marcel A., F. W. V. Rm. 1050, 11 W. 42nd St., New York.
Cory, A. A., 61 Watsessing Ave., Bloomfield, N. J.
DeCamp, H. H., 414 Ella St., Wilkinsburgh, Pa.
Degener, F. S., 1015 Casgrain Ave., Detroit, Mich.
De Salis, H. W., Box 66, Fort Frances, Ont., Can.
Dixon, F. C., 100 Elm Ave., Mount Vernon, N. Y.
Evjen, H. M., Calif. Inst. of Tech., Pasadena, Calif.
Fick, Ernest, A. T. & T. Co., 412 S. Market St., Chicago, Ill.
Fortin, R. P., Elec. & Gas Inspection Ser., 125 Prince William St., St. John, N. B., Can.
Gorrissen, Chas., Hermannstrasse 38, Hamburg, Germany.
Grenfell, Richard R., 442 6th St., Brooklyn, N. Y.
Hamrick, G. R., Sweetwater, Tex.
Harbison, Henry W., R. F. D. 1, Merriam, Kans.
Hardey, John E., Nat'l. Electrical & Engg. Co., Ltd., Box 1055, Wellington, N. Z.
Hedeby, H. V., P. O. Box 414, Sharon, Pa.
Hoyle, E. R., Tex. Elec. Ser. Co., Eastland, Tex.
Hyatt, C. Brown, Camac and Medary Sts., Philadelphia, Pa.
James, Edgar A., 912 S. Poplar St., Allentown, Pa.
Kirkland, E. H., 6701 Cregier Ave., Chicago, Ill.
Klein, F. A., 1215 Locust St., Philadelphia, Pa.
Matthews, R. F., 123 Livingston St., Brooklyn, N. Y.
McDougall, D. J., 1501 W. Pierce St., Phoenix, Ariz.
Montgomery, Douglas, c/o Mrs. E. Armour, 170 S. Marengo Ave., Pasadena, Calif.
Nims, F. D., 70 State St., Boston, Mass.
Noome, C., Catharijnesingel 33, Utrecht, Holland.
Patrick, R. A., 425 Granite St., Reno, Nev.
Perkins, H. L., 129 Marshall St., Petersburg, Va.
Philp, W. M., 433 Morrison St., Niagara Falls, Ont., Can.
Quaas, Richard T., 545 W. 156 St., New York, N. Y.
Rivers, H. D., 298 Central Ave., Lynbrook, L. I., N. Y.
Sachse, A. O., 87 Court St., Newark, N. J.
Saliba, G. J., 311 86th St., Brooklyn, N. Y.
Schwartz, Carl, Int'l. Combustion Engg. Corp., 200 Madison Ave., New York, N. Y.
Sears, J. J., 311 86th St., Brooklyn, N. Y.
Singer, R. H., 2214 Auburn Ave., Cincinnati, Ohio.
Slaboski, H. T., 1441 Main St., Northampton, Pa.
Smedberg, O. L., 916 12th St., Oregon City, Ore.
Stone, Walter, 4501 Malden St., Chicago, Ill.
Stromberg, T. J., Box 1084, P. O. C. Toronto, Ont., Can.
Svensson, Gerhard, c/o Amer. Express Co., 65 Broadway, New York, N. Y.
Syed, Mustafa, 960 S. 9th St., Noblesville, Ind.
Tsatsaron, Nicholas, Central Restuarant, 300 W. 40th St., New York, N. Y.
Velasco, L. R., Apartado 8, Canargo, Cheh, Mex.
Verrier, E. J., The Perak Hydro Elec. Pr. Co., Ltd., Box 109, Ipoh, F. M. S.
Wallis, C. W., 365 Willow St., Waterbury, Conn.
Watts, W. E. G., General Delivery, San Francisco, Calif.
Wheeler, R. E., 345 W. 58th St., New York, N. Y.

A. I. E. E. Section Activities

WHAT ELECTRICITY IS NOT

New York Section to Hear Doctor Karapetoff

On the evening of Thursday, February 13, 1930, the New York Section of A. I. E. E. will hold a general meeting jointly with the New York Electrical Society on "What Electricity is Not." The speaker will be Doctor Vladimir Karapetoff of Cornell University. Doctor Karapetoff who is well known to the Institute membership, will review the various theories which have been developed in the past as to what electricity is or is not. He will then discuss the conceptions of the present day. Demonstrations to emphasize the high spots of the Doctor's talk are being arranged. As this meeting will be of rather unusual interest, admission will be by ticket only. Reservation cards will accompany the Section notice which will be mailed to the membership about the first of February.

RAILWAY SIGNALING AND TOLL CABLE PRACTISE

To be Discussed by Communication Group of New York Section

The next meeting of the Communication Group of the New York Section will consider two distinct topics of interest to communication engineers. The first paper will be entitled "Modern Trends of Long Distance Cable Construction" and will be presented by C. W. Nystrom, General Outside Plant Engineer for the Southwestern Bell Telephone Company at St. Louis. Mr. Nystrom will tell of experiences with the new type tape-armoured toll cable, buried directly in the ground without ducts or conduits, the laying of which has been recently completed by the Southwestern Bell Telephone Co. The talk will be illustrated. The second speaker will be A. H. Rudd, Chief Signal Engineer, Pennsylvania Railroad whose paper is entitled "Railway Signaling and Train Control."

This meeting will be held on Wednesday, February 19th, 1930 in the New York Telephone Building auditorium, 140 West St., New York, N. Y. Prior to the meeting, from 6 to 7:30 p. m., the cafeteria on Floor B of the building will be open for the use of members and guests who care to gather there for dinner and a social hour.

NEW YORK SECTION MEETING

Transportation Group

On March 18th the Transportation Group will have a meeting on "Heavy Electric Traction." There will be two speakers, as

follows: H. W. Pinkerton of the New York Central on "The Cleveland Union Terminal Electrification" and E. L. Moreland of Jackson and Moreland on "The Lackawanna Electrification." Several well-known engineers in the traction field are preparing to discuss both papers. There will also be informal discussion open to all. The meeting will be held in the Engineering Societies Bldg., 33 West 39th St., New York, N. Y., at 7:30 p.m.

LECTURE COURSES FOR ENGINEERS IN CHICAGO

In view of the need felt by practising engineers for opportunities to supplement their technical education, the Education Committees of the Chicago Section and the Western Society of Engineers have endeavored to determine the types of courses which would benefit the largest number of members and the best methods of supplying such courses. A questionnaire distributed by the Chicago Section was used to determine the subjects desired by the largest number.

Arrangements have been made to offer two courses: "Engineering Economics," to be given by Professor E. H. Freeman, Head of the Department of Electrical Engineering, Armour Institute of Technology, Tuesday evenings, beginning January 21, 1930; and "Recent Developments in Electron Physics and Electrochemistry," by members of faculty in Physics and Chemistry at the University of Chicago, Friday evenings, beginning January 17, 1930. Both courses will be given in the rooms of the Western Society of Engineers.

SECOND MEETING OF CHICAGO SECTION POWER GROUP

Over one hundred members braved a characteristic Chicago snow and wind storm on the evening of Thursday, January 9th, to attend the second Power Group meeting of the Chicago Section. The speaker was D. M. Jones, of the Central Station Division of the General Electric Company, from Schenectady, who talked on the relationship between transformer and power system designs. As is the purpose of this type of meeting the talk and discussion under the chairmanship of F. E. Andrews was completely informal and the interest displayed fully justified the action of the Section in instituting these meetings.

Mr. Jones, who proved himself an excellent speaker for this kind of meeting by his conversational tone and responsive humor, laid the groundwork for the discussion by reciting the coincident development of transformer design practises with the progressive uncovering of system problems as the central station industry grew. He characterized the relationship between the manufacturer of equipment and the user as an implied cooperation toward the best interests of the industry as a whole. In such cooperation, there must be a definite recognition by both parties of the limits of responsibility of each. This recognition has crystallized itself until at the present day it is generally understood the user shall state his order to the manufacturer in terms of testable requirements to be applied to the finished equipment. This condition has come about through the fact that the user is now, as he was not in the early days, represented by competent engineering talent that is able to reduce the desired properties of equipment to specific terms. He showed how the duty voltages on transformers had increased with the growing necessity for greater power transferences over lines and how, with the appreciation of the importance of the transformer in functions distinct from voltage changing, its design had responded to very diverse demands. Among these other functions were the furnishing of reactance in the system, making phase changes, establishing ground points, affording paths for harmonics, etc. He continued by adverting to the need for detailed specifications in the purchase of transformers and said that much had been accomplished to facilitate that job by the standards that have been established by the Institute. In discussing the relation of transformer design in reference to a particular system, he brought out that transformers must conform to that system's characteristics and instanced in this connection practises in regard to the limitation of ground current in its effect on system stability. Characteristics of three-winding transformers were given attention and the essential point brought out that in important situations these transformers may not be regarded as the same kind of operating unit as the two-winding type.

Among the matters brought up in the discussion that followed was the question as to what the next higher transmission voltage would be and whether the manufacturers are now in position to contemplate the building of transformers for such higher voltage. Mr. Jones responded that 330 kv. had been set by general agreement as the probable next high step, and that the manufacturers were looking forward to the construction of equipment for this voltage with equanimity. Another question dealt with the fixation of transformer test voltages in relation to percentage taps. The reply to this was that transformers were rated in certain voltage classes irrespective of taps and that even if the taps were taken into consideration there would still remain the question whether the high tap was furnished to supply an actually higher voltage than rated or whether its function was to afford rated voltage under load conditions. Many other detailed questions on transformer characteristics and design were asked of the speaker, and to all of these, Mr. Jones replied in illuminating detail.

On account of its very large membership the Chicago Section is finding that these smaller and more informal group meetings are very worthwhile for the opportunities they afford for members of the section to come, if they desire, into easy personal contact with leaders in the various fields of electrical engineering.

MIDWINTER DINNER MEETING OF PITTSBURGH SECTION

The Annual Midwinter Dinner Meeting of the Pittsburgh Section and the Electrical Section of the Engineers' Society of Western Pennsylvania was held at the Fort Pitt Hotel, Pittsburgh, January 17, 1930. In accordance with the practise followed in the 1928 and 1929 meetings, an inspection trip and conference for the three neighboring Student Branches were held during the day. A report of these activities is published in the Student Activities department of this issue.

The evening session was opened by a dinner in honor of Doctor Harold B. Smith, President of the Institute. During a program presented immediately after the dinner, J. A. Cadwallader, Chairman, Pittsburgh Section, A. I. E. E., presided.

E. C. Stone, Vice-president, Middle Eastern District, was requested by the Chairman to present the prize of $10.00 which had been awarded by three judges for the presentation of the best paper by an undergraduate during the Student Conference held in the afternoon. This prize which was based upon both subject matter and presentation was awarded to B. A. Jones of the University of Pittsburgh, who presented a paper entitled, *Reduction of Cross-Talk in Open Wire Telephone Lines.* J. W. Matson, Jr., of the University of Pittsburgh, who presented a paper entitled, *Man Power*, received honorable mention.

The following addresses were then given by Students:

"Student Papers *versus* Talks by Visiting Engineers," by L. B. McConaghy, Carnegie Institute of Technology.

"Student Branch Activities," by C. E. Moyers, Chairman, West Virginia University Branch.

"The Future of the Engineer—A Student Viewpoint," by I. W. Lichtenfels, University of Pittsburgh.

President Smith gave his illustrated address entitled, "The Quest of the Unknown," which was deeply appreciated by the audience.

The attendance at the evening meeting was approximately 265.

PAST SECTION MEETINGS

Baltimore

Deion Circuit Breakers, by B. P. Baker, Westinghouse Elec. & Mfg. Co. Illustrated. Dinner preceded meeting. December 13. Attendance 80.

Boston

The Technique of Colored and Talking Motion Pictures, by H. L. Danson, R. C. A. Photophone Corp., and L. T. Troland, Technicolor Motion Picture Corp. December 10. Attendance 340.

Committee reports presented. General discussion of Section activities. December 10. Attendance 8.

Cincinnati

Joseph Slepian, Westinghouse Elec. & Mfg. Co., gave a paper on circuit interrupters. Following the presentation of this paper Dr. Slepian explained the theory in the operation of the Deion circuit breaker. Illustrated. December 12. Attendance 70.

Cleveland

Anti-Aircraft Artillery, by Major G. M. Barnes, U. S. Army. Illustrated with slides and moving pictures. December 12. Attendance 309.

Denver

The Application of Dry Ice to Refrigeration, by E. E. Starr, Dry Ice Corporation of America. Dinner preceded the meeting. December 20. Attendance 37.

Detroit-Ann Arbor

Power House Design, by Alex Dow, President, Detroit Edison Co. An inspection trip through the Delray Power House of the Detroit Edison Co. preceded the meeting. Joint meeting with the Detroit Engineering Society. December 10. Attendance 300.

Erie

Film—"The Story of Copper from Mine to Consumer." December 17. Attendance 105.

Fort Wayne

The Preservation of Wood Poles, by Wayne K. Self, Indiana Service Corp.;

The Balancing of Rotating Machinery, by Ray D. Jones, General Electric Co.;

Patents and Inventions, by P. O. Noble, General Electric Co.;

Electro-Mechanical Analogies, by Andrew W. Kramer, Jr., General Electric Co. January 9. Attendance 85.

Houston

Transatlantic Radio Telephony, by John C. Schelleng, Bell Telephone Laboratories, Inc. Moving pictures presented describing the inspection trip to the Freeport Sulphur Co. last month. November 25. Attendance 125.

Service Insurance, by P. H. Robinson, Houston Lighting and Power Co. December 15. Attendance 24.

Iowa

The Application of the Photoelectric Cell to Communication, by J. O. Perrine, American Tel. & Tel. Co. Illustrated. Joint meeting with the Professional Mens' Club of Des Moines and the Engineers' Club of Des Moines. Dinner preceded meeting. December 13. Attendance 250.

Kansas City

Large Turbine-Driven Generators, by S. H. Mortenson, Allis-Chalmers Mfg. Co. Refreshments served. December 16. Attendance 61.

Los Angeles

An Engineer's Impression of Russia, by Joseph S. Thompson, Pacific Electric Mfg. Co. Meeting preceded by a dinner. December 10. Attendance 95.

Louisville

Television and *Sound Pictures*, by George Robinson and William Bailey, Students. *Cooperative Methods of Engineering Education at the University of Louisville*, by Hardin T. Clark, Student. Joint meeting with the University of Louisville Branch. December 19. Attendance 28.

Lynn

The Ascent of the Grepon, by Bradford Washburn. December 18. Attendance 900.

With Allenby in Palestine and Lawrence in Arabia, by Lowell Thomas. November 20. Attendance 1200.

Mercury Arc Rectifiers, by H. D. Brown. December 4. Attendance 98.

Madison

Inductive Interference, by H. R. Huntley, Wisconsin Telephone Co., with demonstrations. Illustrated. December 16. Attendance 120.

Mexico

Methods Used for the Predetermination of Future Loads on a Distribution System, by E. Leonarz, Jr., Mexican Light and Power Co., Ltd. December 10. Attendance 16.

Minnesota

Dinner-Dance. December 11. Attendance 74.

The Application of the Photoelectric Cell to Communication, by J. O. Perrine, American Telephone & Telegraph Co. Joint meeting with the University of Minnesota Branch. December 16. Attendance 460.

Aviation as an Opportunity, by William B. Stout, Stout Metal Airplane Co., Division of Ford Motor Co. Joint dinner meeting with the A. S. C. E. December 18. Attendance 65.

Nebraska

The Quest of the Unknown, by Professor Harold B. Smith, President of the Institute. Illustrated. September 12. Attendance 38.

The Application of the Photoelectric Cell to Communication, by J. O. Perrine, American Tel. & Tel. Co. December 18. Attendance 84.

New York

The Heart of the Lighting System, by O. P. Anderson, Commercial Engineering Section, Edison Lamp Works, Harrison, N. J. Meeting under auspices of the Illumination Group. Demonstrations, lantern slides, and discussion. January 7. Attendance 250.

An Innovation in Decorative Lighting. A private showing of new decorative lighting effects installed in Hotel St. George, Brooklyn, N. Y. By invitation of the Illuminating Engineering Society. January 9. Attendance 1950.

New Switching Locomotives for New York Central, by F. W. Butt, Assistant Engineer, New York Central.

Progress in Oil Engine Design and Application, by L. G. Coleman, Manager Locomotive Dept., Ingersoll-Rand Co. Meeting under auspices of Transportation Group. Lantern slides, moving pictures and discussion. January 13. Attendance 300.

Niagara Frontier

Industry's Most Precious Raw Material, by L. A. Hawkins, General Electric Co., Schenectady, N. Y. Speaker entertained at dinner prior to the meeting. September 20. Attendance 85.

Oklahoma City

Oil Field Electrification, by R. L. Middleton, General Electric Co. December 12. Attendance 80.

Pittsburgh

Latest Developments in Supervisory Control, by R. J. Wensley, Westinghouse Elec. & Mfg. Co., Mansfield, Ohio. Talking moving pictures before and after the meeting. December 10. Attendance 158.

Pittsfield

Some Interesting Recent Aeronautical Developments, by Samuel P. Mills, U. S. Army Air Corps. Illustrated. Dinner preceded meeting. December 17. Attendance 175.

Anglo-American Relations, by Rennie Smith. January 7. Attendance 402.

Portland

Elementary Principles of Airplane Mapping, by Captain Copeland, U. S. A. Engineers. L. A. McArthur, Pacific Power & Light Co., spoke about the present progress in mapping the State of Oregon. Buffet luncheon followed. December 18. Attendance 80.

St. Louis

Structure of Matter, by Rev. James I. Shannon, Dean of the School of Philosophy and Science and Professor of Physics at St. Louis University. Illustrated with lantern slides. December 18. Attendance 24.

Schenectady

Some Recent Changes in Our Attitude Towards the Nature of the Physical World, by Prof. Karapetoff, Cornell University. Discussion followed. December 6. Attendance 250.

The City as an Employer, by Albert H. Hall, Schenectady Bureau of Municipal Research, Inc. Discussion followed. December 20. Attendance 14.

Seattle

Lightning, by C. E. Magnusson, University of Washington. Committee reports presented. December 17. Attendance 58.

Spokane

Informal talk on methods and equipment used in making and reproducing talking moving pictures, by H. R. Day, Electrical Research Products Inc. December 30. Attendance 30.

Springfield

The Deion Circuit Breaker, by R. C. Dickinson, Westinghouse Elec. & Mfg. Co. Illustrated. December 9. Attendance 64.

Toledo

Electrification of Railways, by C. T. Bascom, Westinghouse Elec. & Mfg. Co., illustrated with motion pictures entitled "The Pathway of Progress." Panels showing various methods of catenary construction on display. December 13. Attendance 65.

Toronto

R. E. Smythies, Lincoln Electric Co., presented a paper on electric arc welding. Illustrated with slides. December 13. Attendance 57.

Urbana

The Quest of the Unknown, by Professor Harold B. Smith, President, A. I. E. E. Joint meeting with the Physics Colloquium and Electrical Engineering Society. December 5. Attendance 115.

Utah

Some Modern Concepts in Physics, Orin Tugman, Head of the Dept. of Physics, University of Utah. December 16. Attendance 35.

Vancouver

Mercury Arc Power Rectifiers, by P. M. Gray, General Electric Co., Schenectady, N. Y. Illustrated. October 23. Attendance 70.

The Ruskin and Bridge River Power Developments of the British Columbia Electric Railway Co., by James Lightbody, B. C. Electric Railway Co. Moving picture films exhibited. December 11. Attendance 16.

A. I. E. E. Student Activities

STUDENT CONFERENCE IN PITTSBURGH

The Third Annual Student Conference of the Student Branches at West Virginia University, Carnegie Institute of Technology, and University of Pittsburgh, sponsored by the Pittsburgh Section and the Electrical Section of the Engineers' Society of Western Pennsylvania was held in Pittsburgh on January 17, 1930, in connection with the Mid-Winter Dinner Meeting of the Sections.

During the morning approximately 100 students of the three institutions were conducted through the Bell Telephone Building in Pittsburgh, in which they were given opportunities to see many types of telephone equipment in operation.

The joint conference of the Branches held in the afternoon was opened by J. A. Cadwallader, Chairman of the Pittsburgh Section. A brief address of welcome was given by F. J. Chesterman, Vice-President and General Manager, Bell Telephone Company of Pennsylvania, and a Director of the Institute. President Harold B. Smith gave an address in which he emphasized the advantages to be gained in the Student Branch activities.

Mr. Cadwallader then called upon J. R. Britton, Chairman, Carnegie Institute of Technology Branch, to preside during the presentation of the three papers named below:

Reduction of Cross Talk in Open Wire Telephone Lines, by B. A. Jones, University of Pittsburgh.

Television, by W. S. McDaniel, West Virginia University.

Public Utility Rate Making, by L. B. McConaghy, Carnegie Institute of Technology.

With C. E. Moyers, Chairman, West Virginia University Branch, presiding the following papers were presented:

Engineers and Their Relations with Other People, by W. C. Warman, West Virginia University.

The Institute and the Local Branch, by A. F. Phillips, Carnegie Institute of Technology.

Man Power, by J. W. Matson, Jr., University of Pittsburgh.

In order that the under-graduate students might have opportunities to learn of the experiences of recent graduates of the three schools named above, the following addresses were given with W. A. Aeberli, Chairman, University of Pittsburgh Branch, presiding:

Design in a Large Manufacturing Plant, by A. M. Harrison, Westinghouse Electric & Mfg. Co.

Extraneous Currents in Telephone Circuits, by K. A. Taylor, Bell Telephone Company of Pennsylvania.

Frequency and Its Relation to Telechron Time, by L. T. Kight, Duquesne Light Co.

Mr. Cadwallader again took charge of the session and called upon E. C. Stone, Vice-President, Middle Eastern District, and H. H. Henline, Assistant National Secretary, for brief addresses.

The attendance at this conference was approximately 125. The program was enjoyed by all present. Many of the students attended the dinner and evening meeting held by the two sections. A report on that meeting may be found in the Section Activities department of this issue.

BRANCH ORGANIZED AT TEXAS TECHNOLOGICAL COLLEGE

At the meeting of the Board of Directors held on December 3, 1929, the formation of a Student Branch at the Texas Technological College, Lubbock, Texas, was authorized. This Branch was organized on January 8, 1930 and officers were elected as follows: William E. Street, Chairman; Charles E. Houston, Vice-Chairman; Wilbur L. Pearson, Secretary-Treasurer. Dean William J. Miller has been appointed Counselor.

JOINT SECTION AND BRANCH MEETING IN DALLAS

At a joint meeting of the Dallas Section and the Southern Methodist University Branch held at the University on December 16, 1929, George A. Mills, member of the National Nominating Committee, gave a report on the meeting of the Committee on December 6, Vice-President B. D. Hull reported briefly upon the Great Lakes District Meeting, and the following program on the general subject, *Developments in the Electrical Industry during 1929*, was presented:

Development in High-Tension Transmission, by O. S. Hockaday, Texas Power & Light Co.

The Year's Progress in Underground Distribution, by G. T. Hays, Dallas Power & Light Co.

Hydroelectric Development in the Southwest, by S. M. Sharp, Central and Southwest Utilities Co.

Recent Developments in Central Station Apparatus, by E. M. See, General Electric Co.

Relay Development and Remote Control, by R. W. Roessler, Westinghouse Elec. & Mfg. Co.

Modern Communication Systems in the Southwest, by F. A. Cooper, Southwestern Bell Telephone Co.

Progress in Railway Electrification, by R. G. Wagner, Texas and Pacific Railroad.

New Developments in Household Appliances, by L. M. Miller, Graybar Electric Co.

E. H. Flath, Dean of Engineering at the University, presided during the presentation of the papers on developments. The attendance was 52, nearly equally divided between Institute members and students.

PAST BRANCH MEETINGS

Municipal University of Akron

Light's Golden Jubilee, by Wayne Brewster. Illustrated. Glenn O. Hite, Branch Chairman, discussed the difference between enrolled Students and Institute members. October 11. Attendance 13.

Talk on aeronautics given by W. C. Young, Goodyear Tire & Rubber Co. Meeting preceded by a banquet. December 19. Attendance 90.

Alabama Polytechnic Institute

Election of officers—R. F. Ham, Chairman; G. A. Beavers, Secretary-Treasurer. December 12. Attendance 19.

University of Arizona

The Capacitor Motor, by C. A. Macris, Student. November 1. Attendance 14.

Motor Control at the Pasadena Wind Tunnel, by Wm. Wishart, Student. November 8. Attendance 14.

Electrification of a Large Copper Mine, by E. W. Fredell, United Verde Copper Co. November 14. Attendance 28.

Wide Motion Picture Films, by C. S. McKinley, Student;

Self Shielded Radio Coils, by George Walton, Student. November 15. Attendance 13.

Film—"Hydroelectric Power Production in the New South." November 22. Attendance 13.

Hydroelectric Power, by Clarence Wilcox, Student;

Inspection and Testing of Transformer Oil, by Fred Denny, Student. December 6. Attendance 12.

Business meeting. December 13. Attendance 13.

Armour Institute of Technology

Some Engineering Problems of the Universal Wireless, by P. F. Wareing, Universal Wireless Communication Co. December 6. Attendance 56.

Chicago Civic Opera Stage Lighting Control, by K. R. Ross, General Electric Co. Mr. Ross described the Selsyn Thyratron lighting control system with illustrations. January 10. Attendance 48.

Cooper Union

Radio-Frequency Measurements, by L. Martin, Student. December 18. Attendance 38.

Iowa State College

Film—"The Single Ridge." December 5. Attendance 30.

State University of Iowa

Film—"Principles of Electrostatics."

Care and Maintenance of High-Voltage Equipment, by B. A. Johnson, Student;

Edison Storage Cell, by W. B. Knight, Student. December 11. Attendance 33.

Informal talk by M. B. Latson of the Westinghouse Elec. & Mfg. Co. December 18. Attendance 37.

University of Kansas

Report of the senior inspection trip by T. R. Burgenbaugh, Student. Instructions and illustrations were given on resuscitation. December 6. Attendance 48.

Film—"The Electric Ship U. S. S. *Virginia*." December 18. Attendance 55.

Lewis Institute

Joint business meeting held to discuss plans for the Scientific Exposition to be held in March. December 13.

University of Louisville

Messrs. Robinson and Baily spoke on *Television*, and *Talking Pictures*, respectively. *The Cooperative Plan of the Speed Scientific School*, by H. T. Clark, Branch Chairman. Joint meeting with the Louisville Section. December 19. Attendance 26.

University of Maine

Talks by five students on experiences during summer employment. January 9. Attendance 34.

Marquette University

A. O. Weeks, Weeks Air Corp., spoke on the progress of aeronautics in Europe. Illustrated. Joint meeting with the ASME and ASCE. December 19. Attendance 150.

Massachusetts Institute of Technology

E. S. Mansfield, Edison Electric Illuminating Co. of Boston, spoke on the generation and distribution of electric power and the opportunities offered the electrical engineer in this field. Motion pictures followed. Dinner meeting. December 5. Attendance 320.

Sound Motion Pictures, by Jean V. Kresser, Student;

Automatic Mercury-Arc Rectifier, by Arthur F. Wildes, Student. Discussion followed. Dinner preceded meeting. December 16. Attendance 55.

Michigan College of Mining and Technology

Election of officers. *Some Facts About the General Electric Company*, by W. Keyes. Illustrated. Professor G. Swenson, Counselor, and Frank Sawyer, Branch Chairman, gave talks on the Chicago District meeting. Refreshments served. December 12. Attendance 15.

Michigan State College

Economics of Electrical Distribution, by H. J. Gronseth, Lansing Power Co. December 10. Attendance 16.

Meeting held to discuss plans for the electrical show in February. January 8. Attendance 23.

University of Nebraska

The Application of the Photoelectric Cell to Communication, by J. O. Perrine, American Telephone & Telegraph Co. Illustrated. December 10. Attendance 200.

University of Nevada

Industrial Heating, by C. R. Owens, General Electric Co. Demonstrated. October 2. Attendance 78.

Committee reports presented. Film—"King of the Rails." November 13. Attendance 20.

Aims and Purposes of the A. I. E. E., by C. E. Fleager, Vice-President Pacific Telephone & Telegraph Co., and Vice-President A. I. E. E. Film—"Finding His Voice." November 21. Attendance 178.

Papers presented by students on experiences during summer employment. December 11. Attendance 20.

University of New Hampshire

Film—"Hydroelectric Power Production in the New South."

Demonstration of Convection Currents in Water Heaters, by J. K. Clark, Student;

Telephone Cable Making, by J. F. Tinker, Student. November 16. Attendance 46.

Surveying and the Design of Dam Sites, by Leslie Potts, Student;

Reactors in A. C. Systems, by R. W. Adams, Student. November 30. Attendance 48.

Film—"Building New York's Newest Subway."

Permalloy and Its Use, by B. O. Atwood, Student;

Incandescent Lamps, by R. W. Adams, Student. November 23. Attendance 34.

The Relation of Load to Station Equipment, by P. Morton, Student;

The Operation of the Dial Telephone, by K. Wheeler, Student. December 7. Attendance 45.

College of the City of New York

Inspection trip to the Aubudon Telephone Exchange. December 18. Attendance 22.

Inspection trip to the Mazda Lamp Works, Harrison, N. J. Talks by Messrs. Pilkey, Matters, and Loewe, on illumination. December 23. Attendance 22.

Inspection trip to the long distance and transatlantic telephone exchange of the American Telephone and Telegraph Co. January 8. Attendance 20.

North Carolina State College

Seadromes, by H. R. Acton, Student;

An Account of My Life Since Graduation to Show Obstacles Confronting Graduates, by Professor Glenn. January 7. Attendance 42.

University of North Carolina

Training of British Pilots During the World War, by Fred Merryfield, Graduate Student;

Engineers in Recent History, by Professor Frank Graham. Joint meeting with the A. S. C. E. December 12. Attendance 75.

Northeastern University

Recent Changes in Design of Transmission Lines and Problems Involving Lightning, by Hugh Spencer, New England Power Co. Illustrated. December 10. Attendance 77.

University of Notre Dame

J. P. Kennedy, former student, explained new features of a portable screen grid radio receiver, and reported upon answers received from members of the class of 1929 in electrical engineering regarding the value of their courses in their present positions.

Freak Radio Reception, by H. L. Perry, Student;

Life of Thomas A. Edison, by Mr. Altmann, Student. December 9. Attendance 72.

Ohio Northern University

Lighting of Airways and Airports, by Arthur Nazario, Student;

High-Frequency Currents, by Ralph Bondley, Student. Illustrated. December 5. Attendance 43.

Oklahoma A. & M. College

The Life of Edison, by Wilbur Slemmer, Student. October 17. Attendance 22.

General discussion of activities. December 12. Attendance 20.

Two Films—"Water Power" and "Transportation." January 9. Attendance 22.

Pennsylvania State College

All-day inspection trip. December 14. Attendance 30.

Princeton University

Film—"The World of Paper." December 12. Attendance 8.

Film—"Making of Mazda Lamps." January 9. Attendance 8.

Rensselaer Polytechnic Institute

Tungsten Lamps, by W. E. Mayott, Student;

Neon and Mercury Arc Vapor Lamps, by N. S. Cargill, Student;

Nine-Element Oscillograph, by C. F. Folliott, Student. December 10. Attendance 80.

Rutgers University

The Senior Class Inspection Trip to the General Electric Works at Schenectady, N. Y., by G. E. Weglener, Branch Chairman;

D-C. Equipment on Gas-Electric Busses, by D. M. Jobbins, Student. December 3. Attendance 17.

University of South Carolina

Saluda River Project, by G. H. Preacher, Student;

Virginia Railway Electrification, by C. L. Fishburne, Student. November 22. Attendance 27.

Dial Telephone Systems, by C. C. Chapman, Student;

Radio Communication, by B. F. Karick, Student. December 13. Attendance 28.

South Dakota State School of Mines

Annual Frolic. Student talks by C. Laws, M. Biskeborn, S. Sickel, K. Fenner, R. Burnham, A. C. King, C. Thatcher. Professor J. O. Kammerman, Counselor, gave a talk on the opportunities of an electrical engineer. Refreshments served. December 13. Attendance 63.

University of South Dakota

The Tail Spin, by Enar Johnson, Branch Chairman. December 2. Attendance 8.

The Aero-Glider, by Donald McKellar. December 16. Attendance 7.

University of Southern California

Lumir Slezak, Student, spoke on the recently developed Deion Circuit Breaker. November 27. Attendance 31.

Distribution System, by Arthur Williams, Bureau of Power & Light. December 4. Attendance 35.

Business meeting. December 11. Attendance 34.

Southern Methodist University

Joint meeting with the Dallas Section. Complete report published in Section Activities Dept. December 16. Attendance 52.

Stanford University

C. H. Suydam, Acting Chief Engineer, Federal Telegraph Company, gave an account of the development and present status of his company and described the various things this company is working on at the Palo Alto plant. December 4. Attendance 35.

Inspection trip through the Federal Telegraph Co. December 7. Attendance 35.

Syracuse University

The Induction Furnace, by Louis Frost, Student. December 15. Attendance 13.

The New Deion Circuit Breaker, by Clinton Hurlbut, Student. January 6. Attendance 10.

University of Tennessee

Film—"Hydroelectric Power Production in the New South." January 8. Attendance 20.

Texas A. & M. College

The Dry Cell, by J. W. Mims, Student;

The Lead Cell, by F. R. McIntosh, Student.

Film—"The King of the Rails." December 13. Attendance 99.

University of Utah

Business meeting. January 7. Attendance 20.

Virginia Military Institute

Following talks by students:

Application of Electricity in Coal Mines, by Mr. Walker;

Safety Department of the Alabama Power Co., by Mr. Davidson;

Motion Picture Machine, by Mr. Stokes;

"*Electex*" *the Battery Food*, by Mr. Lindsey. December 21. Attendance 44.

Virginia Polytechnic Institute

Discussion of Branch activities. January 10. Attendance 21.

University of Vermont

Watthour Meters, by F. E. Beckley, Branch Chairman. November 26. Attendance 16.

The Development of A-C. Generators, by R. H. Jeffrey, Student. December 10. Attendance 16.

State College of Washington

Committee appointments announced. What the A. I. E. E. Is, by Professor R. D. Sloan. President Mathison gave a report on his trip to the convention at Santa Monica, Calif. Refreshments served. October 3. Attendance 45.

John Harrington and Harold Squier spoke on their summer experiences while employed by the Commonwealth Edison Co. October 16. Attendance 23.

Lecture by Dean H. V. Carpenter on Light's Golden Jubilee, illustrated with slides. October 21. Attendance 75.

Banquet. Dean Crawford, University of Idaho, was guest and speaker of the evening. October 30. Attendance 61.

Talks by J. Dodds and Merle Poland, Students, on their summer experiences while employed by the Public Service Co. at Joliet, and the White River Power Plant. November 12. Attendance 24.

Film—"Hydroelectric Power Production in the New South." November 26. Attendance 70.

University of Washington

J. E. Burrell elected Branch Secretary. Talk by C. E. Magnusson on his work in Washington. December 6. Attendance 35.

Film—"The Single Ridge." December 13. Attendance 22.

Yale University

F. H. Eastman, Branch Chairman outlined the work and functions of the Branch. Talks by R. B. Whittredge, Branch Treasurer, and A. K. Wing, Branch Secretary. December 12. Attendance 19.

Film—"Electrical Measuring Instruments." December 17. Attendance 30.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these founder societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August, when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, DECEMBER 1-31, 1929

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Baumaschinen.

By H. Feihl. Mün. u. Ber., R. Oldenbourg, 1929. 324 pp., illus., diagrs., tables, 10 x 7 in., cloth. 20.-r. m.

This handbook brings together a remarkable amount of practical information on machinery for construction work. Steam engines and boilers, motor trucks, electric motors, pumps, hoists and conveyers, excavators, compressed air tools, concrete mixers and conveyers, road machinery and all the other equipment of the contractor are described, with data on sizes, output and prices.

A Chemical Dictionary.

By Ingo W. D. Hackh. Phila., P. Blakiston's Son & Co., 1929. 790 pp., illus., ports., diagrs., tables, 10 x 7 in., fabrikoid. $10.00.

In compiling this dictionary, the author has aimed to state clearly and precisely the theories, laws and rules of chemistry; to describe the elements, compounds and other substances of interest, to list the important reactions, processes and methods; mention the apparatus and instruments; and note the names of important chemists. In addition he has tried to include the pertinent vocabulary of other sciences and of industry.

The work has great value as a book of reference. The definitions are concise, yet modern and adequate. A surprisingly large vocabulary is included, sufficient for all ordinary needs.

Colloid Chemistry, Principles and Applications.

By Jerome Alexander. 3rd edition. N.Y., D. Van Nostrand, 1929. (Industrial chemical monographs). 270 pp., 9 x 6 in., cloth. $3.00.

Aims to provide a concise description of the important general properties of colloids, and an account of some of the practical applications of colloid chemistry. Among the latter discussed here are applications to paints and varnishes, lubricants, fuels, sewage disposal, metallurgy, cement, ceramics, as well as many others. The new edition has been much enlarged, and an appendix giving suggestions for simple experiments added.

Der Eisenbau, v.1; Grundlagen der Konstruktion feste Brücken

By Martin Grüning. Berlin, Julius Springer, 1929. (Handbibliothek für Bauingenieure). 441 pp., illus., diagrs., 10x7 in., cloth. 48.-r. m.

Intended as an introductory text-book for students of structural engineering. The first third of the book presents the broad principles, including a discussion of materials, structural shapes and combinations, and stresses and safety. The remainder of the text gives a systematic course of instruction in bridge design. The book is admirably illustrated with drawings and photographs. It should be useful as a convenient reference book.

Die Elektrische Messtechnik, bd. 2.

By G. Brion. Ber. u. Lpz., Walter de Gruyter & Co., 1929. 121 pp., diagrs., 6 x 4 in., bound. 1,50 r. m.

Standard German methods for testing dynamos, transformers and converters are presented concisely in this little book, intended as an introduction to the subject.

Engineering Mechanics, pt. 1; Simple Statics, Dynamics of Translatory Motion, Dynamics of Rotatory Motion.

By William S. Franklin and Zenas R. Bliss. Lancaster, Pa., Franklin & Charles, 1929. 287 pp., diagrs., tables, 9 x 6 in., cloth. $2.75.

A text-book for engineering students, based especially on the views of Kelvin, Tait and Raleigh. The book aims to focus attention on the more fundamental aspects of the subject and to omit much that is not really fundamental.

Fundamentals of Electrical Engineering; Theory and Practise.

By William S. Franklin and Lyman M. Dawes. Lancaster, Pa., Franklin & Charles, 1929. 512 pp., diagrs., tables, 9 x 6 in., cloth. $4.00.

Intended as an introductory text for students of electrical engineering, and also as a text for others who need a basic knowledge of the subject. The author's aim has been "simplicity and directness of theoretical treatment presented on a vividly physical basis with a wealth of practical material."

Graphische Statik, t. 1.

By Otto Henkel, Ber. u. Lpz., Walter de Gruyter & Co., 1929. 150 pp., diagrs., 6 x 4 in., bound. 1,50 r. m.

Presents concisely the principles of the subject and shows its most important practical applications. Intended as an introduction to the study of the subject and also as a concise reference work. The new edition has been revised and enlarged.

Die Gravimetrischen Verfahren der Angewandten Geophysik.

By Hans Haalck. Berlin, Gebrüder Borntraeger. 205 pp., illus., diagrs., 10 x 7 in., paper. 16,80 r. m.

Since the introduction of the Eötvös torsion balance as a practical instrument of geophysics, a large literature has grown up on instrumental improvements and investigations, advances in methods, and practical measurements of various geological objects. This monograph presents a review of the methods now in use and of their place in practical geophysics, with emphasis on applications to mining. An introduction to the general theory underlying the method is included, and many bibliographic references.

Highway Location and Surveying.

By W. W. Crosby and George E. Goodwin. Chic., Gillette Publ. Co., 1929. 398 pp., illus., graphs, tables, 8 x 5 in., cloth. $5.00.

In the first of the three sections that constitutes this book Mr. Crosby discusses in an easy narrative some of the general problems to be considered in relocating highways for modern conditions. Present and possible traffic conditions, speeds and safety, alignment, grades, widths, by-passes, economics and other important topics are treated. Section two on mountain highway construction, by Mr. Goodwin, deals more definitely with the problem of actual design and construction. Section three is a compilation, from field manuals, of instructions on surveying procedure and plans. Appendixes give specimen forms and a bibliography.

Industrial Furnace Technique.

By A. Hermansen. Lond., Ernest Benn, Ltd., 1929. 293 pp., illus., diagrs., tables, 9 x 6 in., cloth. 25 s.

The author of this book, a well-known Swedish designer and manufacturer of industrial furnaces, has long been engaged in developing the mathematical and physical theory of the furnace, so as to place furnace design on a firm scientific basis. This book, of unusual interest to every designer, presents his conclusions, derived from experience and laboratory research, concerning the conditions and calculations to be taken into consideration for different furnace constructions.

Temperature, heat quantity, combustion, the production of high temperatures, fuel, heat transmission, and the movement of gases are discussed theoretically and in relation to furnace design, in the first half of the book. Furnace-building in general is then discussed, after which chapters are devoted to regenerators and recuperators, burners and draft openings, work chambers, calculation of the laboratory working space, furnace materials, supports, starting furnaces, and heat balance. Many useful formulas are given.

Kinematical Design of Couplings in Instrument Mechanisms.

By A. F. C. Pollard. Lond., Adam Hilger, Ltd., 1929. 64 pp., illus., diagrs., 9 x 6 in., cloth. 4s 9d.

The importance of the kinematical design as opposed to the usual machine-tool design of couplings in instrument mechanisms is discussed by the Professor of Instrument Design at the Imperial College of Science and Technology, who points out that design upon kinematical principles not only minimizes variance and difficulty in adjustment, but also simplifies the problems of manufacture. The book is concerned chiefly with indicating instruments, such as ammeters, and value-controlling instruments, such as carburetors, thermostats, governors, and spring motors.

Quantum Mechanics.

By Edward U. Condon and Philip M. Morse. N. Y., McGraw-Hill Book Co., 1929. (International series in physics). 250 pp., 9 x 6 in., cloth. $3.00.

This book aims to give an account of some of the leading developments in our knowledge of atomic structures and the interpretation of spectroscopic and electronic phenomena which have been made since 1924. Building inductively from the phenomena to be explained, the authors set forth, as simply as possible, the prevalent theory of the quantum mechanics, and give an outline of the results obtained by it, with an account of various methods used to arrive at them.

Reference Book of Inorganic Chemistry.

By Wendell M. Latimer and Joel H. Hildebrand. N. Y., Macmillan Company, 1929. 442 pp., diagrs., tables, 9 x 6 in., cloth. $3.75.

A book on descriptive chemistry which interprets it in terms of modern theories of valence, atomic structure and simple thermodynamics. Chemical properties are throughout related to atomic structures and sizes. The formulas of many compounds are given in terms of the Lewis theory of valence. "Half reaction" potentials are tabulated extensively, many being new. For its size, the book contains a remarkable amount of essential factual data, expressed briefly and clearly.

Report Writing.

By Carl G. Gaum and Harold F. Graves. N. Y., Prentice-Hall, 1929. 319 pp., 9 x 6 in., cloth. $5.00.

Certain principles of composition and rhetoric are here applied to the writing of reports, in a course of practical instruction which begins with the writing of business letters and advances progressively to complex forms. Specimen outlines and reports form a second part of the text, to which several useful bibliographies are appended. The book offers a good foundation course in its subject.

Das Schaltwerk....der Siemens-Schuckertwerke.

By Hans Dominik. Berlin, S. Hirzel, 1929. (Musterbetriebe Deutscher Wirtschaft, bd. 11; Der Schaltgerätebau). 86 pp., illus., 9 x 6 in., boards. Price not indicated.

A detailed description of the new plant for manufacturing switchgear of the Siemens-Schuckert Works in Berlin. The construction and arrangement of the buildings and the methods for the planning and control of production are explained, with the aid of numerous illustrations.

The book is one of a series designed to show, by describing typical modern examples, the way in which Germany is adopting modern ideas of scientific management.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contribution from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

RECENT GRADUATES, electrical engineers interested in a combination of research and practical work in a rubber insulating plant. Apply by letter. Location, New England. X-9772.

STRUCTURAL STEEL DRAFTSMEN. Apply by letter. Location, New England. X-8527.

ENGINEER, electrical engineer graduate, young, to enter sales department in connection with sale of miscellaneous heavy duty types of storage batteries; for instance, oil switch, emergency lighting and motive power installations. Opportunity. Apply by letter. Location, Maryland. X-7776.

RECENT GRADUATE, electrical engineer, for sales work. Apply by letter. Location, New York City. X-9930.

CHIEF ENGINEER, experienced and qualified to manage established engineering department with full responsibility for the design development, and performance of standard and special electric motors. Company manufactures fractional horsepower a-c. and d-c. motors. Apply by letter giving complete information as to age, education and experience, stating companies with which connected, duration of connection, character of work and compensation received, also names of references familiar with recent work. Apply by letter. Location, Middle west. W-253-C.

ELECTRICAL ENGINEER, familiar with design of small capacity air circuit breakers. Apply by letter. Location, Middle west. W-261-C.

MECHANICAL AND ELECTRICAL ENGINEERS, Eastern Utility has opportunity for

recent graduates on training course leading to permanent positions in generating, distribution and sale of electric power. Excellent opportunity to those who can qualify. Please state age, education, experience and salary desired. W-423.

MECHANICAL ENGINEER, who is interested in design of transformer tanks, radiators, tap-changing mechanisms, and other parts, from the standpoint of simplification of manufacture, cost reduction, and standardization of parts. Would work with design engineers and the factory in connection with these matters. Should be familiar with steel plate and tank fabrication in which electric welding is used extensively. Apply by letter. Location, Pennsylvania. X-9589.

MEN AVAILABLE

ELECTRICAL ENGINEER, married, graduate, 20 years' experience in design, estimating, and construction of copper smelters, refineries and electrolytic plants, also familiar with concentrator and steel mill practise, many years with A. G. McGregor and Anaconda smelter. Desires responsible position as engineer, chief draftsman or in similar capacity. Available within two weeks. B-7343.

SALES ENGINEER, electrical training at W. P. I. Six years' sales and executive experience Prefer opportunity to develop sales or assist in management. Willing to travel. Headquarters in Central Connecticut desired. C-5431.

GRADUATE ELECTRICAL ENGINEER, experienced in substation and central station drafting and construction with large middle west utility. Desires position in sales or making reports with prospects of advancement. Available on short notice. Location, immaterial. C-6809.

ELECTRICAL ENGINEER, experienced in management, electrical utilities including construction and maintenance, transmission lines, power houses; also auditing and load building. Wide experience in sales and sales management for large electrical manufacturer of electrical and steam apparatus. Age 48, with family, capable of assuming responsibility. C-6817.

ELECTRICAL ENGINEER, 29, American Citizen, five years' experience, general testing, laboratory standardization work, charge of electrical testing instruments, special tests. Ability in report writing, absolutely reliable. Desires position in electrical research or development of electrical machinery with manufacturing concern. At present employed but available short notice. Location, vicinity of New York. B-8751.

ASSISTANT EXECUTIVE, 38, married, technically trained. Connections with large public utility, manufacturers and industrial consultants on work of administrative and commercial nature. Especially qualified as assistant to busy executive needing man with management ability. Well endorsed. Prefer East. B-9122.

CONSULTING ENGINEER, desires position as executive with public utility or manufacturer. Twenty years' experience in consulting practise covering design, construction, valuation, and operation of public utilities. Broad experience in engineering and commercial fields, sales promotion, research work, etc. B-8084.

PUBLIC UTILITY ENGINEER, Graduate Electrical Engineer, 38, now employed, ten years' experience valuations electric, gas properties, rates, economic reports new properties, other regulatory problems. Thoroughly familiar with Public Utility accounting principles, laws, financing. Five years' experience electrical construction work. Desires permanent position large public utility holding, operating company or financial house. B-1205.

ELECTRICAL ENGINEER, university graduate, 30, experienced in design, of power plants and substations, economics, export, foreign languages; Spanish and German. Location, United States, or abroad. Available on short notice. C-3534.

ELECTRICAL ENGINEER—B. S. and M. S. in electrical engineering, M. I. T. General electric test and central station dept. Engineers' training course with large utility. Desires position with public utility or firm of consulting engineers. Available about February 15. Location, immaterial. C-2753.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, 20 years' experience in power plant and general engineering work, design, construction and operation. Desires position with public utility, consulting engineer or construction company. State of Ohio or adjoining states preferred. B-4144.

ELECTRICAL ENGINEER, B. S. H. E. E. Six years' experience in large public utility engineering department, power plant and substation electrical design, installation, inspection, testing and maintenance. Available on month's notice. Location, United States or South America. C-6853.

ELECTRICAL ENGINEER, 30, married, six years' experience in generation, distribution, industrial plant, design, supervision of construction. Desires connection with consulting engineer, vision of construction or as assistant plant engineer. Willing to assume responsibility. Northern New Jersey or New York preferred. Now employed. C-6834.

ENGINEER, graduate E. E., 37, business training, industrial, public utility, and sales experience. Good personality, capable of handling men. Qualified by training and experience, for executive or administrative position. Desires position with public utility power sales, or in engineering department of an industrial plant. Location, Middle west. C-3616.

ELECTRICAL AND SAFETY ENGINEER, 31, married, experienced in design, layout, installation and maintenance of industrial substations, distribution systems, motor applications, control-lighting, etc. Also experienced in promoting safety educational programs. Ten years' with present concern. Desires position in charge of electrical department, or as assistant to factory engineer. Location, East. C-6870.

VALUATION ENGINEER, 30, married, B. S. in E. E., two years' teaching in electrical department of large university, two years' with telephone company, five years' in valuation and appraisal of public utility electric property, including street railways. Desires similar position with utility or appraisal company in middle or far west. B-8982.

ELECTRICAL ENGINEER, 32, married, twelve years' experience, light, heat, power. Wide experience, construction, maintenance, operation of mill installations, public buildings, etc. Desires connection American concern with opportunity for foreign travel, to design new installations or install, maintain equipment. Advancement primary importance. Available short notice. C-6892-301-C-4.

ELECTRICAL ENGINEER, married, wide experience; construction, operation, maintenance, sugar mill installations, street lighting. Past ten years had complete charge of hydro and steam plants, transmission, 200 motors, large synchronous motor driven centrifugal pumps, capacity over 100 M. G. D. Over 25 years' experience. Now employed. Location, any Rocky Mountain States. C-6683.

ELECTRICAL ENGINEER, GRADUATE, age 32, thorough theoretical knowledge, radio experience covering development of apparatus and measuring equipment and investigations of communication problems. Desires position offering opportunity for development work. Foreign languages, German and French. Eastern location preferred. C-5545.

ELECTRICAL ENGINEER, Lehigh graduate, age 39, with well-rounded industrial and editorial experience gained in mining, steel, public utility, and technical publishing fields. Desires position (not editorial) commensurate with qualifications and ability. C-6906.

RADIO ENGINEER, wide experience covering transmission, commercial broadcasting, power equipment all classes. Receiver and power amplifier, talking picture equipment. 35, married, read, write and speak Spanish. Travel no objection. Available two weeks' notice. C-3784.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting of January 23, 1930, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

MURPHY, FRANCIS H., Chief Illumination and Rate Engineer, Portland Electric Power Co., Portland, Oregon.

NORRIS, ERIC T., Chief Designer, Ferranti, Ltd., Hollinwood, Lancashire, England.

To Grade of Member

ADAMS, IRA J., Patent Lawyer, 41 Park Row, New York, N. Y.

CORY, MERTON M., Associate Prof. of Elec. Engg., Michigan State College, East Lansing, Michigan.

DILLARD, EDWARD W., Electrical Engr., New England Power Assoc., Boston, Mass.

JOHNSON, WAYNE N., Asst. Distribution Station Engr., Bureau of Power & Light, Los Angeles, Calif.

LaMOND, Wm. H., Manager, Simplex Wire & Cable Co., Cleveland, Ohio.

LANE, H. S., Asst. Engr., Pacific Gas & Elec. Co., San Francisco, Calif.

LONG, CARL C., Specification & Inspection Engr., Southern Calif. Edison Co., Los Angeles, Calif.

MANASERI, BENJAMIN B., Eastern Division Engr., Postal Tel. Co., New York, N. Y.

O'BRIAN, WILLIAM C., Plans Engr., Stevens & Wood, Jackson, Michigan.

ROXBURY, WALTER R. O., Elec. Engr., New Yorker Hotel Corp., New York, N. Y.

RUSH, HARRY S., Prof. of Elec. Engg., North Dakota Agricultural College, Fargo, N. D.

SMITH, NELSON E., Manager, Chace Electric Co., Fall River, Mass.

SWIFT, FRANK E., Designing Engineer, English Electric Co. of Canada, Ltd., St. Catharines, Ont., Canada.

WOOSTER, LAWRENCE F., Prof. of Applied Electricity, Oregon State College, Corvallis, Oregon.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 28, 1930.

Alimansky, M. I., General Electric Co., Pittsfield, Mass.
Appel, H. W., Radio-Victor Corp., Camden, N. J.
Archibald, L. W., Southern Sierras Power Co., Hemet, Calif.
Ashton, E. R., Westinghouse Elec. & Mfg. Co., Tacoma, Wash.
Auld, J. R., Canadian General Electric Co., Peterboro, Ont., Can.
Auld, W. F., Canadian General Electric Co., Peterboro, Ont., Can.
Ayers, J. W., General Electric Co., Fort Wayne, Ind.
Barker, R. W., General Electric Co., Pittsfield, Mass.
Bassett, W. H., Jr., (Member), Anaconda Wire & Cable Co., Hastings-on-Hudson, N. Y.
Battey, L. J., General Electric Co., Salt Lake City, Utah.
Beedle, R. H., New England Power Co., Boston, Mass.
Bell, L. C., Duquesne Light Co., Pittsburgh, Pa.
Benin, Z., King Mfg. Corp., Buffalo, N. Y.
Bond, M. E., American Bosch Magneto Corp., Springfield, Mass.
Boodberg, P., Pennsylvania Power & Light Co., Mount Carmel, Pa.
Bowers, K., International Paper Co., Glens Falls, N. Y.
Bradway, I. E., Western Electric Co., Kearny, N. J.
Brauch, H. N., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Brimberg, M., Radio Counsellors, Inc., New York, N. Y.
Bristol, F. J., Cornell University, Ithaca, N. Y.
Brooks, L. F., New England Power Association, Boston, Mass.
Brown, A. S., University of Arkansas, Fayetteville, Ark.
Buchanan, G. E., Delta-Star Electric Co., Chicago, Ill.
Calnan, T. J., Duquesne Light Co., Pittsburgh, Pa.
Carlsen, O. K., Postal Telegraph-Cable Co., New York, N. Y.
Carnevale, O. A., Narragansett Electric Co., Providence, R. I.
Carroll, J. F., Western Electric Co., Newark, N. J.
Chambers, D. E., General Electric Co., Schenectady, N. Y.
Champeny, G. C., Western Electric Co., Cicero, Ill.
Chaphe, G. F., Portland Electric Power Co., Portland, Ore.
Christman, F. J., Allis Chalmers Mfg. Co., Milwaukee, Wis.
Clark, E. J., (Member), Byllesby Engineering & Management Corp., Pittsburgh, Pa.
Clements, V. O., Westinghouse Elec. & Mfg. Co., Houston, Tex.
Crossman, G. C., Brooklyn Edison Co., Brooklyn, N. Y.
Darling, T., Jr., Pennsylvania Power & Light Co., Allentown, Pa.
Decorte, V. J., Commercial Cable Co., New York, N. Y.
Denman, A. B., Southwestern Bell Telephone Co., Houston, Tex.
Detsch, A. S., 322 Security Bldg., Portland, Ore.
Dixon, J. E., University of Missouri, Columbia, Mo.
Doughtie, H. J., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Driscoll, J. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Dunlap, S. B., Western Electric Co., Kearny, N. J.
Dunleavey, F. S., Sprague Specialties Co., Quincy, Mass.
Dunn, C. H., (Member), Canadian General Electric Co., Toronto, Ont., Can.
Durgin, H. L., Twin State Gas & Electric Co., Boston, Mass.
Eckels, C. E., American Tel. & Tel. Co., Pittsburgh, Pa.
Ecker, L. F., Illinois Power & Light Corp., East St. Louis, Ill.
Fischer, L., J. V. Cremonim, New York, N. Y.
Friday, C. D., Sargent & Lundy, Chicago, Ill.
Gallik, A. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Gardner, G. A., (Member), Philadelphia Co., Pittsburgh, Pa.
Gaulke, A. T., Kansas City Power & Light Co., Kansas City, Mo.
Gilbert, W. E., Atwater Kent Mfg. Co., Philadelphia, Pa.
Gilpin, F. P., Kansas City Power & Light Co., Kansas City, Mo.
Greene, C. R., Western Electric Co., Inc., Kearny, N. J.
Griffitts, J. A., Bureau of Power & Light, Los Angeles, Calif.
Hackett, G. R., (Member), Holtzer-Cabot Electric Co., Cincinnati, Ohio
Hall, J. E., Blackstone Valley Gas & Electric Co., Pawtucket, R. I.
Hall, S. M., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Hausske, G. A., Sargent & Lundy, Inc., Chicago, Ill.
Hawley, A. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Hess, H., Sargent & Lundy, Chicago, Ill.
Hettel, E. F., Duquesne Light Co., Pittsburgh, Pa.
Hill, V. E., Duquesne Light Co., Pittsburgh, Pa.
Hoffmann, D. C., General Electric Co., Philadelphia, Pa.
Hoffmann, W. W., Victor X-Ray Corp., Chicago, Ill.
Holland, G., Electric Bond & Share Co., New York, N. Y.
Hovey, B. K., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Hull, V. O., Borg-Warner Corp.; Marvel Carburetor Co., Flint, Mich.
Jogeese, M. G., Electric Storage Battery Co., New York, N. Y.
Johnson, P. L., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Jones, R. D., General Electric Co., Fort Wayne, Ind.
Joyce, S. F., Jr., Union Electric Light & Power Co., Webster Groves, Mo.
Kerlin, W. D., (Member), Shenandoah River Power Co., Harrisonburg, Va.
Kerrigan, A. L., Charles H. Tenney & Co., Boston, Mass.
Kershaw, John, Westinghouse International Co., New York, N. Y.
Kissinger, A. A., 813 Walnut St., Reading, Pa.
Klemm, C. A., (Member), Tofel Electric Co., Louisville, Ky.
Koepp, F. W., Illinois Power & Light Corp., Belleville, Ill.
Krachy, A. C., J. D. Brance Co., Houston, Tex.
Langley, S. P., Westinghouse Electric International Co., New York, N. Y.
Lawrence, W. L., Bell Telephone Laboratories, Inc., New York, N. Y.
Lehr, C. N., J. E. Perkins Co., Inc., Baltimore, Md.
Leihy, C. W., General Electric Co., Seattle, Wash.
Lindsley, C. M., Southern Sierras Power Co., Riverside, Calif.
Link, A. L., 50 Fruehauf Ave., Snyder, N. Y.
Long, H. H., Knoxville Power & Light Co., Knoxville, Tenn.
Lueking, H. A., Union Electric Lt. & Pr. Co., Webster Groves, Mo.
Madden, J. B., (Member), Pacific Gas & Electric Co., San Francisco, Calif.
Maiese, D., American Brown Boveri Co., Camden, N. J.
Marco, F. J., (Member), Audiola Radio Co., Chicago, Ill.
Marsh, M. O., General Electric Co., Fort Wayne, Ind.
Marter, W. E., Duquesne Light Co., Pittsburgh, Pa.
Martin, H. R., Keller-Pike Co., Philadelphia, Pa.
McCordick, A. S., (Member), Moloney Electric Co. of Canada, Ltd., Toronto, Ont., Can.
McMorris, W. A., General Electric Co., Pittsfield, Mass.
Messinger, L. E., Canadian Line Materials, Ltd., Scarboro Junction, Ont., Can. (Applicant for re-election.)
Metes, J. M., General Electric Co., Schenectady, N. Y.
Miller, L., Electric Bond & Share Co., Merida, Yuc., Mexico
Mitchell, J. G., Pennsylvania Power Co., Sharon, Pa.
Miyauchi, M. H., Tokizawa & Co., New York, N. Y.
Morgan, T. O., Buick Motor Co., Flint, Mich.
Morris, L. P., University of Illinois, Urbana, Ill.
Moxey, L. W., Keller-Pike Co., Philadelphia, Pa.
Mueller, H. A., O. U. Zerk, Chicago, Ill.
Murphy, W. J., (Member), Canadian Utilities, Ltd., Calgary, Alberta, Can.
Murray, H. T., Central West Public Service Co., Omaha, Nebr.
Musgrove, A. M., Jr., Public Service Corp. of N. J., Newark, N. J.
Neidig, R. E., Metropolitan Edison Co., Reading, Pa.
Nelson, G. H., Hankscraft Co., Madison, Wis.
Nicholson, C. P., Jr., Cutler-Hammer, Inc., Milwaukee, Wis.
Nimetz, J. B., 397 Arguello Blvd., San Francisco, Calif.
Noble, J. A., Lockport Light, Heat & Power Co., Lockport, N. Y.
Ohrn, C. T., Cape & Vineyard Electric Co., Hyannis, Mass.
Parkhurst, E. L., National Broadcasting Co., Oakland, Calif.
Pattison, R. E., Philadelphia Electric Co., Philadelphia, Pa.
Peterson, H. J., Westinghouse Elec. & Mfg. Co., Seattle, Wash.
Phillips, W. C., (Member), New England Power Construction Co., Boston, Mass.
Phillips, W. H., Edward J. Cheney, New York, N. Y.
Pike, O. W., General Electric Co., Schenectady, N. Y.
Plass, C. W., (Member), Plass Engineering Corp., Oakland, Calif.; Kansas City, Mo.; Philadelphia, Pa.
Pratt, W. G., New England Power Construction Co., Boston, Mass.
Preisel, E. A., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Quinter, L. R., Reading School District, Reading, Pa.
Ramey, P. T., Union Electric Light & Power Co., St. Louis, Mo.
Rapport, A. H., New York Edison Co., New York, N. Y.
Rearick, E. C., Western Electric Co., Kearny, N. J.
Reeves, H. J., New York & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
Richardson, D. E., (Member), Armour Institute of Technology, Chicago, Ill.
Robertson, C. B., Wisconsin Telephone Co., Milwaukee, Wis.
Rorden, H. L., General Electric Co., Pittsfield, Mass.
Ross, C. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Rulofson, C. H., Pacific Gas & Electric Co., San Francisco, Calif.
Rusie, A. E., Electric Service Co., New York, N. Y.
Sandberg, S. I., City & County of San Francisco, San Francisco, Calif.
Sawyer, R. E., International Tel. & Tel. Co., New York, N. Y.
Schilha, V., Western Electric Co., Kearny, N. J.
Schmutz, G. H., West Penn Power Co., Pittsburgh, Pa.
Schonvizner, M. S., Carnegie Institute of Technology, Pittsburgh, Pa.
Segall, B. Z., New Orleans Public Service, Inc., New Orleans, La.

Sharp, J., Brown Instrument Co., Philadelphia, Pa.
Siebert, F. F., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Slack, F. G., International General Electric Co., Schenectady, N. Y.
Smith, B. K., International Derrick & Equipment Co., Columbus, Ohio
Smith, L. R., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Sorieri, M. A., American Tel. & Tel. Co., New York, N. Y.
Spahr, V. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Sparr, A. E., New York Edison Co., New York, N. Y.
Spicer, W. H., Ferris Industrial School, Marshallton, Del.
Stanley, P. R., Delta-Star Electric Co., Chicago, Ill.
Stearns, C. M., Duquesne Light Co., Pittsburgh, Pa.
Stewart, J. M., Gulf States Paper Corp., Braithwaite, La.
Stoos, J. A., Delta Star Electric Co., Chicago, Ill.
Stratton, G. F., Armature Winding Co., Charlotte, N. C.
Sullivan, J. E., Victor X-Ray Corp., Chicago, Ill.
Swingle, W. M., Chesapeake & Potomac Tel. Co., Richmond, Va.
Tanenbaum, M., Board of Education, City of New Brooklyn, N. Y.
Taylor, R. C., Western Union Telegraph Co., New York, N. Y.
Thurston, M. G., Wardell Thurston Electric Co., Buffalo, N. Y.
Touraine, E. J., Western Electric Co., Kearny, N. J.
Towle, H. C., Jr., Bell Tel. Co. of Penna., Harrisburg, Pa.
Townsend, C. S., Eclipse Aviation Corp., East Orange, N. J.
Tracy, S. J., University of Pittsburgh, Pittsburgh, Pa.
Troughton, J. A., Jr., Pringle Electrical Mfg. Co., Philadelphia, Pa.
Tsuruda, M., Japanese Government Railways, New York, N. Y.
Van Inwegen, J. W., Trojan Engineering Corp., New York, N. Y.
Voils, T. W., Westinghouse Elec. & Mfg. Co., Louisville, Ky.
Warren, H. F., Edison Electric Illuminating Co. of Boston, Waltham, Mass.
Wasson, E. A., General Electric Co., Fort Wayne, Ind.
White, H. D., Richfield Oil Co. of Calif., Los Angeles, Calif.
Whitman, J. A., Western Electric Co., Chicago, Ill.
Williams, J. T., Sargent & Lundy, Inc., Chicago, Ill.
Wilson, R. F., General Electric Co., Fort Wayne, Ind.
Wilson, R. S., Duke Power Co., Charlotte, No. Car.
Winter, N. L., General Electric Co., Fort Wayne, Ind.
Yogerst, W. M., Globe-Union Mfg. Co., Milwaukee, Wis.
Zavers, M., General Electric Co., Schenectady, N. Y.
Total 177

Foreign

Bhandari, R. C., Brown Boveri & Co., Baden, Switzerland
Chandhuri, K. M., Bogra Electric Supply Corp., Ltd., Bogra, Bengal, India
Cursedjs, J., Indian Government, Bombay, India
Day, A. F., Municipal Council of Sydney, Sydney, N. S. W., Australia
Munshi, D. P., (Member), B. T. Mills, Ltd., Burhanpur R. S., Via Bombay, India
Murty, P. K., (Member), Consulting Mechanical & Electrical Engineer, Agraharam, Guntur, South India
Rangnekar, M. S., G. I. P. Railway, Bombay, India
Row, D. P., Engineering College, Karachi, India
Semenza, M., (Member), Via Monte Napoleone, 39, Milano, Italy
Singh, B., Jullundur Electric Supply Co., Ltd., Sargodha, Punjab, India
Singh, G. B., Saharanpur Electric Supply Co., Saharanpur, U. P., India
Spruce, A. M., General Electric Co., Witton, Birmingham, Eng.
Total 12

STUDENTS ENROLLED

Abadjoglou, Naki G., Robert College
Abramson, Ralph J., Armour Institute of Tech.
Ackerman, C. Julian, University of Minnesota
Ackerman, Fred L., Oregon State College
Ackman, H. H., University of Illinois
Adachi, Susumu, Tokyo Imperial University
Adams, Rolly O., University of Cincinnati
Adcock, Herbert V., Ohio University
Aldape, Vicente C., Texas A. & M. College
Alexander, Moultrie M., N. C. State College
Alger, James A., Jr., Virginia Polytechnic Institute
Alleman, James J., Louisiana State Univ.
Allen, Fisher W., University of Alabama
Allen, Robert B., University of Missouri
Allison, Charles H., Iowa State College
Anastasi, Joseph J., Mass. Inst. of Technology
Anderson, Dale W., University of Michigan
Anderson, Idof, Jr., Worcester Polytechnic Inst.
Anderson, Karl H., Georgia School of Technology
Anderson, Roy H., Newark College of Engineering
Arbour, Willard L., Louisiana State University
Armstrong, Delbert A., Purdue University
Arnold, George E., Rhode Island State College
Artamonoff, Nicolas V., Robert College
Ashmore, Orbon B., Southern Methodist Univ.
Askew, John D., Jr., Georgia School of Technology
Atwater, Eugene, California Institute of Tech.
Austin, Everly W., University of Colorado
Autuori, Louis A., Yale University
Babcock, Charles M., Ohio University
Bailey, Frank William, Missouri School of Mines & Metallurgy
Bailey William E., University of Louisville
Baker, C. B., Virginia Polytechnic Institute
Baker, Joseph J., Louisiana State University
Ball, Hugh E., Univ. of Notre Dame
Ballas, Joseph J., Pratt Institute
Barber, Arley R., Virginia Polytechnic Institute
Barnett, Glen, Oregon State College
Barnett, Howard E., University of Cincinnati
Barnett, Jorge I., Mass. Inst. of Technology
Baron, Adolph R., Missouri School of Mines & Metallurgy
Barrett, Robert E., Worcester Polytechnic Inst.
Barry, John S., University of Notre Dame
Bartunek, Paul F., University of Nebraska
Baskerville, Robert J., University of Notre Dame
Batcheller, J. Raymond, Oregon State College
Bassiliades, Demetrius, Robert College
Baudino, Louis J., University of Colorado
Baumann, George H., Pratt Institute
Beaird, B. J., Southern Methodist University
Beavers, Barney, N. C. State College
Beavers, George A., Alabama Polytechnic Inst.
Becker, E. K., Pratt Institute
Beckle, Karl, University of Wyoming
Beckmann, Harold P., Brooklyn Polytechnic Inst.
Beckmeyer, E. W. C., Pratt Institute
Beckwith, Edmund Q., Iowa State College
Bedi, Fahir, Robert College
Beeman, Sheldon P., Rensselaer Polytechnic Inst.
Behn, Victor D., Cooper Union
Belda, James C., University of Nebraska
Bemis, Roy I., University of Minnesota
Benard, Frederick, McGill University
Bennett, Joe, University of Nebraska
Besler, H. J., Kansas State Agricultural College
Best, Jess W., Jr., Ohio University
Bezdjian, Mihran Z., Robert College
Birchard, Wayne E., Iowa State College
Bishop, George R., University of Illinois
Bixby, W. Herbert, University of Michigan
Bjork, Roy E., Montana State College
Black, Harold A., Montana State College
Black, R. J., Ohio State University
Blair, Frank O., University of Wyoming
Bloom, Jefferson D., Jr., University of Detroit
Boehmer, Donald, Marquette University
Bond, Donald H., Louisiana State University
Bonney, Edgar G., Northeastern University
Bookhardt, Fred B., Georgia School of Tech.
Boren, Jack S., California Institute of Technology
Bosman, Ivan, Marquette University
Bost, Winston A., University of Arkansas
Boul, Leon B., Pratt Institute
Bourne, Richard D., University of Cincinnati
Braun, Margil, University of Texas
Breitowich, Paul, University of Illinois
Bretholl, Carl F., Jr., Duke University
Briansky, David, Cooper Union
Brigandi, Philip E., Cornell University
Briggs, Robert B., University of Texas
Brintzenhoff, Trimble O., Oregon State College
Brooks, Robert E., University of South Carolina
Brosnan, John D., Catholic University of America
Brower, William E., Miss. A. & M. College
Brown, William A. A., Pratt Institute
Bruce, William D., University of Pennsylvania
Brugger, Richard L., Iowa State College
Brumbaugh, John McC., Univ. of Pennsylvania
Bryan, Colgan H., University of South Carolina
Buchak, Kirk, University of Minnesota
Buckman, Frank E., University of Washington
Buckwalter, James N., Yale Univ.
Budelman, Frederick T., Cornell University
Bunker, Ralph G., Pratt Institute
Burch, Charles H., Georgia School of Technology
Burdette, Dana N., Univ. of Pittsburgh
Burglund, Wilfred P., University of Illinois
Burke, William J., Pratt Institute
Burmeister, Herbert, Cooper Union
Burns, Walter N., Texas Technological College
Byram, F. Cameron, University of Michigan
Cady, Richard C., University of Minnesota
Caldwell, B. H., University of Texas
Callaghan, James L., Louisiana State University
Campfield, W. B., University of Va.
Carlson, Frank L., University of Michigan
Carroll, Charlton H., Univ. of Pittsburgh
Carserino, Nicholas A., Pratt Institute
Catanese, Sam J., University of Detroit
Chabot, Raymond L., Univ. of Pittsburgh
Chandler, James L., N. C. State College
Chapman, Cecil C., University of South Carolina
Chen, George H., Cornell University
Chewning, Arthur W., Iowa State College
Chiles, John D., Virginia Polytechnic Inst.
Chin, Stanley Q. W., Worcester Polytechnic Inst.
Christoferson, Everett W., Univ. of Minnesota
Christoff, Elias C., University of Akron
Clare, Louis, Yale University
Clark, Howard S., Cooper Union
Clarke, Chester M., University of Michigan
Cline, Truman H., Purdue University
Cobb, Hilary J., N. C. State College
Coffin, Edward C., Jr., Georgia School of Tech.
Cohagan, Clifford F., Oregon State College
Cole, Myron C., University of South Dakota
Collins, Patrick J., Southern Methodist University
Combs, Gilbert U., Kansas State Agri. College
Comstock, Roy H., University of Minnesota
Cook, Chauncey W., University of Texas
Cooper, Frederick W., Univ. of Colorado
Corbett, Robert G., Oregon Institute of Tech.
Cottony, Herman Y., Cooper Union
Countryman, Clarence, Pratt Institute
Cowles, Harper B., University of Utah
Cox, Sidney L., Oklahoma A. & M. College
Crain, Robert A., Louisiana State University
Cramond, Robert B., Pratt Institute
Crawford, Charles E., University of Arkansas
Crawford, Vernon E., Texas Technological College
Creighton, John E., Ohio Univ.
Crenshaw, Rice F., Georgia School of Technology
Crippen, Alfred H., Iowa State College
Croft, Walter H., Univ. of Alabama
Crowson, Fred B., Jr., N. C. State College
Cunliff, Robert G., Oregon State College
Curry, L. M., University of Texas
Curtis, W. F., Louisiana State University

Curtiss, Lawrence M., Pratt Institute
Cuthbert, Donald, Carnegie Institute of Tech.
Cutler, Harold T., Worcester Polytechnic Inst.
Dana, Charles A., Univ. of Colorado
Danner, Clayton E., University of Washington
Daun, Gordon T., University of Michigan
Darley, William G., Texas A. & M. College
Davidson, Leonard, Armour Inst. of Technology
Davidson, Murray, Montana State College
Davis, Elmer R., University of North Carolina
De Garmo, Ernest P., University of Washington
Delk, Charles C., Mississippi A. & M. College
Dial, Louis H., Georgia School of Technology
Dillett, George A., Marquette University
DiMeo, Saverio,, North Carolina State College
Diveley, Chester L., University of Colorado
Doane, Charles W., Jr., University of Michigan
Dormer, John M., Catholic University of America
Dostaler, Oliver L., Marquette University
Double, C. R., University of Colorado
Douglas, George W., Missouri School of Mines & Metallurgy
Dow, Donald C., Columbia University
Doyle, Tom C., University of Washington
Drake, Francis E., University of North Carolina
Draus, Andrew R., Armour Institute of Technology
Drennen, Sidney W., Virginia Polytechnic Inst.
Dresen, James P., University of Colorado
Drigot, William, Armour Institute of Technology
Dunn, Thomas J., Catholic University of America
Dwyer, Raymond C., University of Nebraska
Dyer, J. M., Texas Technological College
Eaton, Richard K., Northeastern University
Eberle, Edward R., Yale University
Eddy, Charles B., Worcester Polytechnic Institute
Edgell, Earnest E., University of Minnesota
Edgett, Clinton, Ohio University
Edwards, Robert B., Montana State College
Eggers, Evrett B., University of Minnesota
Ehrenhard, Phil, University of Nebraska
Eichenlaub, Vincent J., University of Notre Dame
Ekstrand, Philip A., Oregon State College
Elgaard, James A., University of Nebraska
Ellett, Robert T., III, Pratt Institute
Elsea, Daniel S., Virginia Polytechnic Institute
Elwell, Wilfred W., University of Iowa
Emery, William F., Colorado State Agricultural College
Entrekin, H. R., Purdue University
Epps, William A., Mississippi A. & M. College
Estep, Walter B., Ohio University
Estes, Wm. M., Jr., Clemson A. & M. College
Eudaly, Sheldon, Texas Technological College
Eumer, Ali N., Robert College
Fairfield, Emmet C., University of Illinois
Falkner, Thurston L., University of Alabama
Fellers, Harold N., Clemson A. & M. College
Fenn, Fred H., Louisiana State University
Fentress, Frank L., N. C. State College
Ferdinand, John, University of Texas
Ferns, J. H., Stanford University
Ferris, Robert M., Jr., Yale University
Filman, Paul T., Pennsylvania State College
Filmer, James C., Armour Institute of Technology
Finch, Edward H., University of Minnesota
Fish, Edwin L., University of Michigan
Fisk, Daniels B., Yale University
Forbes, Allan D., University of Michigan
Fortino, Sam, City College of New York
Foster, C. Dalton, Oregon State College
Foster, James E., University of Missouri
Foster, Thomas L., University of Alabama
Foster, Troy, Texas Technological College
Foster, Walter S., Virginia Polytechnic Institute
Foster, William M., Clemson Agricultural College
Fox, Richard S., Armour Institute
Fracker, Henry E., Calif. Inst. of Tech.
Franks, Alvin E., University of Colorado
Frear, William, Penna. State College
Freeman, Adam J., University of Colorado
Freer, F. Hervey, Rensselaer Polytechnic Institute
Frellsen, Carlton B., Lewis Institute
Freyman, David B., University of Detroit
Friedman, Sherman S., University of Pittsburgh
Friel, Henry F., Worcester Polytechnic Institute
Fuchs, Marcellus Wm., Univ. of North Dakota
Fussell, Lewis, Jr., Swarthmore College
Gable, Frank H., Southern Methodist University
Gadeken, Frank G., University of Colorado
Gamiere, Charles L., Case School of Applied Science
Gardner, Edwin R., Mass. Inst. of Tech.
Gallay, Harris, College of the City of New York
Gavina, Serafin, Georgia School of Tech.
Gavitt, Harold T., Pratt Institute
Geers, Henry, Yale University
Getchell, Bayard M., University of Washington
Gillham, William T., Georgia School of Technology
Ginsberg, Alvin M., Cooper Union
Glasscock, Glen R., Pratt Institute
Glenn, James R., Virginia Polytechnic Institute
Glenn, Maurice T., Texas Technological College
Goldman, Reuben, Cooper Union
Goodman, B. I., Pratt Institute
Gould, Leonard A., Georgia School of Technology
Grantham, Ward H., Georgia School of Tech.
Gravley, Charles K., Oregon State College
Greene, Nathan J., Georgia School of Tech.
Greenlee, Kenneth, University of Illinois
Grigg, Wilfrid E., University of Michigan
Grimm, Claude J., Missouri School of Mines & Metallurgy
Grivet, Paul E., Washington University
Haber, Albert F., Oklahoma A. & M. College
Hachemeister, Charles A., College of the City of New York
Hackley, Reginald A., Yale University
Hadley, Raymond F., Rensselaer Polytechnic Institute
Hall, Jack Wellington, Georgia School of Tech.
Hall, John R., Georgia School of Tech.
Hanna, Elmer E., University of Akron
Hanners, Harvey W., University of Wisconsin
Hanson, Rudolph M., University of Minnesota
Harmer, Harland D., University of Minnesota
Harrower, George A., Univ. of British Columbia
Harry, Joe H., University of Cincinnati
Hart, Harry C., University of Pennsylvania
Hartman, Horace H., N. C. State College
Hausen, Raymond E., Univ. of Pittsburgh
Haymes, Terrell W., Texas Technological College
Head, Ernest W., University of Arkansas
Heaton, Henry T., Rensselaer Polytechnic Inst.
Heckman, Vernon J., University of Illinois
Hedding, Linnie K., University of Michigan
Heller, Gabriel, New York University
Hemphill, R. K., University of Iowa
Hencir, Joseph W., Pratt Institute
Hendel, Arthur T., Ohio University
Henderson, Carl E., University of New Mexico
Hendrick, Thomas G., Texas Technological College
Hendrix, Harold B., University of Alabama
Herbert, Verell C., University of Texas
Herbruck, Robert A., Leigh University
Hereford, Robert E., University of Alabama
Hessney, Abbott L., Cornell University
Highley, Samuel G., University of Missouri
Hinton, David A., Jr., University of Pittsburgh
Hirai, Hiromu, Tokyo Imperial University
Hirmke, Albert W., Pratt Institute
Hixson, Arthur C., Pennsylvania State College
Hjelm, Ralph H., University of Denver
Hobbs, Charles F., University of North Dakota
Hodge, F. Eldred, Northeastern University
Hoekstra, Cyrus E., University of Nebraska
Hoepke, George J., University of Pennsylvania
Hoffmann, Harold E., Cooper Union
Hogan, James F., Pratt Institute
Hogan, O. D., Mississippi A. & M. College
Hogendobler, Henry R., University of Illinois
Holmes, Robert A., University of Notre Dame
Holsenbeck, William M., Jr., Georgia School of Technology
Holzschuh, William C., Pratt Institute
Honnell, Pierre M., Texas A. & M. College
Hope, Henry W., Ohio State University
Hopkins, Albert F., Jr., University of Minnesota
Horan, Thomas M., Univ. of Notre Dame
Hosack, Gayle R., Kansas State Agricultural College
Hoss, Walter B., Oklahoma A. & M. College
Houston, Charles E., Texas Technological College
Houston, Louis B., Southern Methodist Univ.
How, John H., Stanford University
Howard Charles A., South Dakota State College of A. & M.
Howell, Hamilton, Oregon State College
Howell, John C., Georgia School of Technology
Howell, William J., University of Pittsburgh
Hratz, Joseph A., University of Iowa
Hubbs, Clarence J., Brooklyn Polytechnic Inst.
Hughes, Dan W., Armour Institute of Technology
Hunter, Julian C., Georgia School of Technology
Hustrulid, Andrew, University of Minnesota
Hutchinson, Mideon C., N. C. State College
Hutchinson, Walter, J. B., McGill University
Illian, Douglas F., Mass. Inst. of Tech.
Iskiyan, Haig S., Jr., University of Michigan
Jackson, Arthur J., Univ. of Pittsburgh
Jacobs, Wm. A., University of Minnesota
Jamart, Gustave E. J., Stanford University
James, Clayton A., Rensselaer Polytechnic Inst.
James, Marvin R., Missouri School of Mines & Metallurgy
Janes, C. Howell, University of Florida
Jani, Robert W., Case School of Applied Science
Jenkins, Thomas W., University of Alabama
Jewett, Lawrence E., Swarthmore College
Johannes, Sam J., University of Southern Calif.
Johnson, D., University of Washington
Johnson, George V., University of Minnesota
Johnson, Harold J., University of Colorado
Johnson, P. J., West Virginia University
Johnson, Reynold, Pratt Institute
Jones, Arthur A., Mass. Inst. of Tech.
Jones, Clevoe D., University of Michigan
Jones, James K., Georgia School of Technology
Joyce, Robert C., Johns Hopkins University
Jucciarone, Nicholas T., Cooper Union
Junttila, Paul, Michigan College of Mining & Technology
Kalen, C. Lloyd, Iowa State College
Kastens, Robert H. C., Cooper Union
Kauffman, Lloyd S., Jr., Pratt Institute
Keisling, W. N., Texas A. & M. College
Keith, Harold A., Georgia School of Technology
Kelch, Russell V., Ohio University
Kelsey, Edwin W., Louisiana State University
Keltz, Laurence, University of Colorado
Kernahan, Richard H., University of Pittsburgh
Kerschgens, William J., University of Pittsburgh
Kesler, Thomas S., University of Nebraska
Kieselbach, Richard A., University of Missouri
King, Charles N., Pratt Institute
Kinkade, Verle, University of Wyoming
Kintner, James G., Purdue University
Kirkpatrick, D. N., Lafayette College
Knocke, Walter A., Armour Institute of Tech.
Kochevar, John S., University of Minnesota
Kolks, Richard H., University of Cincinnati
Kopf, Clemons M., Kansas State Agricultural College
Koup, Elmer L., Louisiana State University
Koutnik, Ernest A., University of Colorado
Kraft, Theodore W., University of Louisville
Kreibich, Carl E., Armour Institute of Technology
Kresser, Jean V., Mass. Inst. of Tech.
Kristiansen, A. T., Pratt Institute
Krueger, R. John, University of Nebraska
Kuhlman, Paul W., University of Michigan
Kunins, Morris K., New York University
Kurkjian, John M., Mass. Inst. of Technology
Kurtz, Lowell M., Montana State College
Kuwano, Douglas, University of Colorado
Kuykendal, Franklin B., Jr., University of North Carolina
LacCoste, Lucien J. B., University of Texas
Laine, Mauno W., University of Alabama
Lamb, Anthony H., Newark College of Engineering
Lamb, Francis X., Newark College of Engineering
Lambert, John L., University of Notre Dame
Lamey, Robert H., Swarthmore College
Lamparski, H. C. L., University of Pittsburgh
Landon, Grant K., University of Oklahoma
Landsiedel, John H., Brooklyn Polytechnic Inst.
Lane, William L., Ohio University
Lang, Lloyd L., University of Michigan
Langevin, Lawrence J., University of Cincinnati
Lash, Charles C., California Inst. of Technology
Lassiter, Neil H., Jr., Georgia School of Tech.
Latta, Alexander, Cornell University

Lecky, Robert S., Virginia Polytechnic Institute
Lee, David R., University of Southern California
Lefkowitz, Mortimer, Cooper Union
Lefler, Lloyd E., University of Nebraska
Leiss, Edward A., Newark College of Engineering
LeJeune, Clarence E., Louisiana State University
Le Sage, Charles Wm., University of Michigan
Lev, Nathan, University of Pennsylvania
Levy, Nathan, College of the City of New York
Lewis, James H., Clemson College
Lewis, John R., Iowa State College
Lewis, Warren J., University of Cincinnati
Libby, Charles C., University of North Dakota
Lidman, Carl H., University of Minnesota
Lindley, Bayron, University of Texas
Lindsay, Vernon H., Northeastern University
Lindsey, Orel B., University of Alabama
Lips, John G., University of Louisville
List, Harold A., Georgia School of Technology
Locke, Harry E., University of Illinois
Lodal, Olaf, Texas Technological College
Loehr, Albert H., 3rd., Northeastern University
Love, Heilbron B., University of Michigan
Lovinggood, Lecton W., University of Texas
Lower, Robert, University of Colorado
Lowrimore, Wm., Jr., Texas Technological College
Loye, Edward S., University of Minnesota
Ludwig, Norman C., Lewis Institute
Luedtke, Walter H., University of Notre Dame
Luethi, Frank E., University of Colorado
Lukey, Myron E., Armour Institute of Technology
Lytton, Charles W., Case School of Applied Science
Lytton, Robert O., University of Texas
Mackey, Jack M., University of Washington
Mackie, Fred W., Oklahoma A. & M. College
MacDonnell, Sam, Jr., Pratt Institute
Mahalak, Alfred F., University of Detroit
Malloy, James A., University of Notre Dame
Malmquist, C. L., Pratt Institute
Mangelsdorf, Harold G., Kansas State Agricultural College
Marando, Humbert S., Armour Inst. of Tech.
Marcy, Gerald P., Worcester Polytechnic Inst.
Marofsky, Henry J., University of Minnesota
Martin, J. Russell, University of Detroit
Martinez, Florentino S., University of Iowa
Mathis, Loyd B., Oklahoma Agricultural & Mechanical College
Matsumoto, Masanori, Tokyo Imperial University
Mauk, Gaylord S., Case School of Applied Science
May, G. W., University of Arkansas
Mayleas, Ludwig B., Columbia University
Maynard, John S., Johns Hopkins University
McBroom, Marvin F., University of Alabama
McCleery, Everett C., Catholic University of America
McCleskey, Roy G., Georgia School of Technology
McClure, Robert F., Rensselaer Polytechnic Inst.
McCraw, James L., State University of New Mexico
McCuiston, Ted, Oklahoma A. & M. College
McDonald, Harold M., University of Missouri
McDonald, Leon, University of Arkansas
McDougall, Roger A., University of Denver
McFarland, Ottis H., Mississippi A. & M. College
McGovern, E. H., Jr., Pratt Institute
McKeen, Edwin O., Oregon State College
McKeever, James L., Univ. of British Columbia
McKeever, Stanley K., Cooper Union
McKellar, John D., University of South Dakota
McLaughlin, R. B., Pratt Institute
McNally, Irvin L., University of Minnesota
McNarney, John H., University of Notre Dame
Medrano, Jose C., Jr., Mass. Inst. of Technology
Meece, Frank H., North Carolina State College
Meeks, Harold W., Mississippi A. & M. College
Merlin, Manuel I., University of Alabama
Merriman, Frank J., Case School of Applied Science
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Seattle	(9)	L. N. Robinson	George S. Smith, Elec. Engg. Dept., University of Washington, Seattle, Wash.
Sharon	(2)	J. B. Gibbs	S. S. Cook, Westinghouse E. & M. Co., Sharon, Pa.
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Urbana	(5)	M. A. Faucett	C. E. Skroder, Univ. of Ill., Urbana, Ill.
Utah	(9)	A. C. Kelm	L. B. Fuller, Utah Pr. & Lt. Co., Salt Lake City, Utah
Vancouver	(10)	J. Teasdale	D. Robertson, Canadian Gen. Elec. Co., Ltd., Vancouver, B. C., Canada
Washington	(2)	W. A. E. Doying	G. L. Weller, Chesapeake & Potomac Tel. Co. & Assoc. Cos., 725-13th St., N. W., Washington, D. C.
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Alabama, Univ. of, University, Ala	(4)	R. M. Phillips		
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Colorado, University of, Boulder, Colo	(6)	Wm. J. Dowis	George B. Steuart	W. C. DuVall
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Synchronous Motors.—Bulletin GEA-1191, 88 pp. Describes G-E synchronous motors, illustrating numerous applications. General Electric Co., Schenectady, N. Y.

Commutator Undercutter.—Bulletin, 4 pp. Describes Martindale lathe type, motor driven undercutter for shop use. The Martindale Electric Co., 1254 West 4th Street, Cleveland, O.

Motor Generators, Dynamotors, and Inverted Converters.—Bulletin No. 1001-A, describes various types of converting apparatus of the rotary type such as is used in connection with storage battery charging, fire alarm signals, telephones, wireless apparatus, dental and X-Ray appliances. The units described are all of fractional horsepower ratings. Bodine Electric Company, 2254 W. Ohio Street, Chicago.

Series Intermittent Service Motors.—Bulletin No. 1007-A, describes alternating and direct-current series intermittent service motors with speed reducers, for applications requiring a reliable slow speed drive at comparatively small horsepower. These motors have ratings from 1/80 to 1/15 hp. Bodine Electric Company, 2254 W. Ohio Street, Chicago.

New Dynamic Braking Controller for Crane Hoists.—The Electric Controller & Mfg. Co. of Cleveland, Ohio, has made announcement of the "Wright Dynamic Lowering Circuit Controller," magnetic contactor type, and intended for use on crane, ore and coal bridge, and bucket hoists. The improved device insures faster crane operation, more accurate control of short, quick movements and better ability to spot loads. Other outstanding advantages claimed are greatly reduced power consumption at all speeds, reduced power peaks, less motor heating and less contactor wear.

Submarine Cables.—Bulletin 200A, 64 pp., a handsomely bound brochure describing Siemens loaded submarine telephone and telegraph cables. The opening chapter deals with loading in a general way, while successive chapters contain illustrated descriptions, supplemented by copious tabular matter, of coil-loaded and continuously-loaded telephone cables insulated with gutta-percha and paper respectively, and continuously-loaded gutta-percha insulated telegraph cables. A brief mathematical treatise on telephonic and telegraphic transmission is given in an appendix. Siemens Brothers & Co., Ltd., London, S. E. 18.

NOTES OF THE INDUSTRY

Illinois Electric Porcelain Co. Enlarges Factory.—The Illinois Electric Porcelain Company, Macomb, Illinois is completing a new steel and concrete addition to their factory that adds 10,000 square feet of space to the wet process department for high tension insulators.

Ohio Brass Opens Office in Seattle.—In order to better serve its customers in the Northwest, the Ohio Brass Company with general offices at Mansfield, Ohio, has opened a branch office in Seattle, Washington. The new office with J. W. Watkins in charge, is located in the Northern Life Tower.

G-E Offices in Philadelphia are Moved.—The Atlantic district and service departments of the General Electric Company at Philadelphia have been moved from the Witherspoon Building, which they had occupied for 22 years. The sales and engineering departments now occupy the 17th, 18th, and 19th floors of the Mitten Building, Broad and Locust Streets. The service departments, also formerly located in the Witherspoon Building, together with the warehousing units and the service shop, are now located in the General Electric building at 429 North 7th Street, formerly occupied by the switchgear factory and abandoned upon completion of the new factory buildings at 69th and Elmwood Avenue.

The Rockbestos Products Corp., New Haven, Conn., has opened a district sales office at No. 2143 Railway Exchange Bldg., St. Louis, Mo. F. W. Allen who has been connected with the Chicago sales office of this company will be in charge.

E. H. Clark has joined the selling organization of the Rockbestos Products Corporation. He will be connected with the Chicago district office.

New Self-Lubricating Bearing.—A new self-lubricating bronze bearing, said to be the only one of its kind, has been announced by Johnson Bronze Company, New Castle, Pa., makers of bronze bushings, bronze bearings, bronze castings, cored and solid bar bronze. According to P. J. Flaherty, president and general manager of the company, the new bearing provides for a uniform area of bearing surface on the pressure line, and insures an efficient distribution of lubricating compound. The compound used is also a Johnson Bronze development.

Asbestos Magnet Wire.—The Rockbestos Products Corporation of New Haven, Conn., manufacturers of asbestos insulated wires and cables, announce a new magnet wire with asbestos insulation, and having a uniform diameter no greater than double cotton covered magnet wire; size 15 B & S Gage and smaller, at much lower prices than heretofore. This new magnet wire at lower cost is made possible by an entirely new process developed by Rockbestos engineers. The new magnet wire can be used in motors, coils, etc., in the same space formerly occupied by double cotton covered magnet wire. Bulletin No. 60 fully describes the new product.

Increased Business with Russia in 1929.—Orders placed by the Amtorg Trading Corporation for shipment to the Soviet Union aggregated $94,500,000 during the calendar year 1929, nearly three times the purchases for 1928, which totaled $32,300,000. The purchases by other firms doing business in this country on behalf of Soviet organizations declined somewhat, but sales of Soviet products showed an increase. The total Soviet-American trade for 1929 is estimated at $155,000,000 as compared with $101,000,000 in 1928. According to U. S. customs statistics American-Russian trade in the last five prewar years averaged $45,469,000. Amtorg purchases of industrial and electrical equipment rose from $12,650,000 in 1928 to $40,200,000 last year.

Large Traction Equipment Order to Westinghouse.—The Board of Transportation of the City of New York Recently placed an order for 610 traction motors and 300 controls with the Westinghouse Electric and Manufacturing Company. The order for this equipment amounts to more than two and one-half million dollars. All of the new equipment will be used on the 300 cars to be operated on the new Eighth Avenue Subway.

Record Hydroelectric Generators for Russia.—Four 77,500-kv-a. hydro-electric generators, the largest in the world, are being manufactured by the General Electric Company for the Dnieper River development at Kichkas, near Zaporozhe, in the Ukraine. The development will supply power in the vicinity of Dnepropetrovsk, and through the southern part of the Union of Socialist Soviet Republics.

The total weight of each generator will be approximately 1,760,000 pounds, while the weight of the rotor and shaft will approach 980,000 pounds. These vertical generators will be driven by water turbines being built by the Newport News Shipbuilding and Dry Dock Company. Hugh L. Cooper and Company, New York, consulting engineers, are now at work on the construction of the dam and power station.

Increased Current Sale in New York.—The sale of electric energy by The New York Edison Company and four associated companies in 1929 was 9.8 per cent greater than in 1928, according to Matthew S. Sloan, president. Sales for 1929 amounted to 3,674,193,914 kilowatt-hours, an increase of 359,879,015 over the 1928 figure of 3,314,314,898 kilowatt-hours.